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Impact of biorational pesticides and response of annexin gene expression in tomato *(Solanum lycopersicum)* and capsicum (*Capsicum annum* L.) in biotic stress management under greenhouse condition

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ABSTRACT

Protected cultivation of high value cash crops such as capsicum and tomato is gaining momentum in recent times. Among various diseases and pests; bacterial wilt, thrips and root knot nematodes are recurrent threats to its production. Biorational pesticides such as agricultural spray oil and azadirachtin are more acceptable than conventional insecticides as they are known to be sufficiently active against pest populations and are relatively safer to beneficial organisms. The experiment was conducted on relative efficacy of agricultural spray oil, azadirachtin and combination of both (1%) for the management of these three different types of biotic stresses on tomato and capsicum under protected cultivation. Results revealed that in all the tested insecticides, the integrated treatments were most effective in comparison to the individual interventions. To investigate common signaling mechanism of response towards these stressors, we carried out RNA expression analysis of an annexin gene. Annexins belong to a family of membrane and calcium (Ca^{2+}) binding proteins which can characteristically bind membrane phospholipids in a reversible, Ca^{2+}-dependent and independent manner. Here we report that the expression of annexin is induced in response to three biotic stress treatments of the crops viz bacterial wilt, thrip infestation and root knot nematode infection. Results show potential evidence that modulation of a single signaling protein can be useful in management of three different and common biotic stressors in tomato and capsicum.

Key words: Biorational pesticide; green house; tomato; capsicum; annexins; transcript expression.

Protected cultivation of vegetables offers distinct advantages of better quality, higher productivity and favorable market price to the growers. Tomato and capsicum are major greenhouse crops of India particularly because they can be grown round the year. Various biotic factors like insects, diseases and nematodes are the major challenges in protected cultivation. Tomato thrips *(Frankliniella spp. and Scirtothrips spp.)* pierce and collapse the plant cells resulting in the formation of deformed flowers, leaves, stems, shoots, and fruits besides causing the greatest threat to many crops, through the thrips-vectored tomato spotted wilt virus (TSWV). Bacterial wilt is one of the major diseases of tomato and capsicum caused by the *Ralstonia (Pseudomonas) solanacearum,* with symptoms of rapid wilting and death of plants without yellowing or spotting of leaves. Among nematodes, root-knot nematode *(Meloidogyne incognita)* is one of the most economically damaging plant-parasitic nematodes causing the development of root-knot galls that drain the plant's photosynthate and nutrients. Owing to growing consumer demands for healthy and green produce, Integrated Pest Management (IPM) programmes using biorational pesticides are being increasingly used in greenhouse production. The use of good agricultural practices (GAP) and IPM are being increasingly advocated in protected cultivation (Sabir *et al.*, 2010). Biorational pesticides such as agricultural spray oils and azadirachtin have been shown to be effective against the most common pests of protected cultivation (Sabir *et al.* 2011; Deka *et al.*, 2011; Sabir *et al.*, 2012).

Agricultural spray oils are commercial by-product of petroleum industry. They can effectively control sucking pests and can be used in combination with common insecticides and pesticides under integrated pest management program (USPTO Patent Application 20080194704). Azadirachtin is a natural biorational pesticide derived from neem tree. It is growth regulating, antifeedant and repellent compound for phytophagous insects (Menke and Gerhard, 2009). Combinations of biopesticides have showed synergistic activity. In earlier studies we have shown that combination of agrospray and azadirachtin at 1% and 2% were most effective, as compared to either of the individual components alone (Deka *et al.* 2011; Sabir *et al.*, 2012). Soil application and foliar spraying of azadirachtin was found to be highly effective for developmental inhibition of root knot nematode in sweet potato concluding that soil application of neem based formulations would be applicable for the control of soil pests (Lynn *et al.* 2010). In another report, strategies alternative to chemical soil fumigation for the control of the root-knot nematode was found to be effective with neem oil application by drip irrigation in tomato field (Sabir *et al.*, 2010). In this study, we report management of three common pests and diseases of greenhouse i.e. bacterial wilt, thrips and root knot nematodes in tomato and capsicum using the treatments of agricultural spray oil, azadirachtin and combination of both.

Although various control measures with inconsistent results are available for green house pest management, molecular analysis for identifying the genes involved in biotic stress responses in green house conditions have not been reported till date. Plants are sessile organisms and are under continuous threat from abiotic and biotic stresses that limit their productivity. Plant react to changing environmental conditions through immediate signal transduction pathways. One integral path of these signal transduction mechanism is usage of free calcium ions as secondary messages. A wide variety of signals, including biotic, abiotic and developmental stimuli evoke specific spatio temporal calcium transients which are further transduced by Ca^{2+} sensor proteins into a translational and metabolic response (Stael *et al.*, 2012).

Plant annexins are ubiquitous, soluble, Ca^{2+} and phospholipid binding proteins. They have been found to represent at least 0.1% of the total protein in all the species studied so far (Cantero *et al.* 2006, Clark *et al.*, 2012). The multifunctionality of plant annexins and their importance for coordinating development and responses to various environmental cues and biotic factors have been variously reported and reviewed (Baucher *et al.*, 2012, Clark *et al.*, 2012). Many studies on global gene and proteome expression analysis have also shown annexins to be amongst the genes expression of which is consistently and differentially altered by various biotic and abiotic stressors. One recent emerging theme is that annexins participate in adaptation of plants to multiple abiotic and biotic stresses at least in one way through its peroxidase activity vide scavenging ROS produced during various stress conditions (Mortimer *et al.*, 2008, Laohavisit and Davies 2011, Clark *et al.*, 2012).A few reports further confirm annexin involvement in multiple biotic stress response. Vandeputte *et al.* (2007) showed that a tobacco annexin gene is induced upon *Rhodoccocus fascians* infection and during leafy gall development. Ectopic expression of an annexin from mustard in tobacco showed resistance to biotic stress when challenged by a host-specific fungal pathogen *Phytophthora parasitica* by the reduced spread of the disease symptoms (Jami *et al.*, 2008). Involvement of annexins in legume root nodulation and arbuscular mycorriza root symbiosis has also been reported (DeCarvalho *et al.*, 1998; Manthey *et al.*, 2004).

Expression analysis is the first step towards functional characterization of any genes. In the present study, we examined transcript expression patterns of one annexin family gene from tomato *(AnnLe p35)* using RTPCR and analysed the relative fold change in transcript modulation under these three biotic stresses in both the crops. We found that annexin is positively and differentially modulated under all the three different biotic stresses relative to uninfected control plants thereby indicating its potential involvement in stress tolerance.

MATERIALS AND METHODS

Raising of plants and bio rational pesticide treatments

The trials were conducted in the greenhouse of Centre for Protected Cultivation Technology (CPCT), Indian Agricultural Research Institute, New Delhi for two seasons during 2010-11-12 with 3 treatments for managing pests of tomato *cv.* Pusa Ruby and capsicum *cv* Orobelle in plot size of 6×1 sq.m for each replicate in a randomized block design (RBD) with 8 replications maintaining the spacing at 60 × 60 cm for tomato and 45 × 30 cm. for capsicum. A border row of crop was planted between each replicate. The experiment was conducted twice and maintained under the same greenhouse conditions. Recommended package of practices were followed for all the treatments. Seed treatment and seedling bare root dip treatment were done with the respective pesticide treatments. Spraying was done on infested plants, two weeks after natural pest infestation based on pest load on the crop when the population exceeded recommended treatment thresholds. Pesticides were applied along with irrigation water for controlling nematodes. Plants were not watered the day before pesticide applications to allow the soil to dry slightly before applying pesticides and three sprays were applied at an interval of 10 days.

The biorationals included agricultural spray oils, azadirachtin and combination of both at 1% each along with control. The control plants were maintained in the greenhouse with no pesticides and were naturally infested with thrips, bacterial wilt and root knot nematode. Pest data were recorded randomly considering five plants/replication for each biotic stress separately and converted to percent infestation. For sampling thrips population, three leaves (top, middle and bottom) per plant were considered. Observations were made after 1, 3, 7 and 10 days after spraying. Soil samples were collected from the rhizosphere region, 5- 6 cm away and at a depth of 8-10 cm from the root base of the plant for recording nematodes at the time of bed preparation and termination of the experiment. Initial population of J2 (second stage juvenile) of nematodes *Meloidogyne incognita* in soil was recorded using Cobb's method of decanting and sieving followed by the modified Baermann`s technique for nematode extraction from soil samples before planting, while root gall index was recorded for the level of root knot infestation. The final nematode count in the soil and the root gall index were recorded on the date of termination of the experiment. The observations on the root gall index as 1-5 scale (Heald *et al.*, 1989) nematode population in soil at harvest were recorded. The data for pest incidence were pooled for both the seasons in all 3 biotic stresses. Results were expressed as percent mortality, percent incidence and root gall index in thrips, bacterial wilt and root knot nematode, respectively. The data obtained were converted by transformations and subjected to statistical analysis (Gomez and Gomez, 1984) and ANOVA tests.

RNA isolation and RTPCR expression profiling

Tomato and capsicum leaves naturally infected by bacterial wilt, thrips and root knot nematodes along with normal uninfected leaves were harvested from greenhouse with proper care; wrapped in aluminium foil, frozen in liquid N_2 and stored at –80°C until further use. Protocols used for this experiment were isolation of RNA by Trizol (Invitrogen, Carlsbad, CA, USA) following manufacturer's protocol, evaluation of quality of RNA by gel electrophoresis using tris-borate EDTA buffer (TBE), DNase Treatment (Invitrogen, Carlsbad, CA, USA). for removing contaminating DNA, quantification of RNA by Nanodrop spectrophotometer (Thermo Scientific, Waltham, MA, USA), first strand cDNA synthesis from 1 ug of total RNA using reverse transcriptase (VERSO -cDNA Kit, Thermo Scientific, Waltham, MA, USA) and oligodT primer, amplification of target cDNA by PCR using Taq DNA polymerase (Promega, Madison, WI, USA) with tomato annexin gene specific primers using an equal amount of 200ng cDNA. Thermal cycler was programmed as 94°C for 4 minutes, 35 cycles of 94°C for 45 sec, 50°C for 45 sec and 72°C for 1 minute. Equal amount of amplified products were loaded in each well and subsequently expression was analyzed on 1.2% TBE agarose gel. To check equal loading and quality control RT-PCR was done using primers for actin, a constitutive housekeeping gene, which showed equal expression of actin in all the samples. Semi quantitative estimation of annexin expression to assess their differential induction after various biotic stimuli was carried out in a gel documentation system using the Syngene software version 4:02.03 (Syngene, Cambridge, UK) with at least three biological replicates of each cDNA sample. The primer sequences used in PCR reactions are as follows :

AnnLep35 : Forward: 5′ AAGCACAGCTGAGT G3′;
Reverse : 5′ ATCCCATTCGTCTGTACCCAG CTT 3′;
Actin : Forward: 5'AGCGAGTCTTCATA GGGCGATTGT 3';
Reverse : 5' TAGCTCTGGGTTCGAGTGGCA TTT 3'

RESULTS AND DISCUSSION

Effectiveness of biorational pesticides

The data on efficacy of insecticides for the control of thrips, bacterial wilt, and root knot nematodes in tomato and capsicum using the treatments of agricultural spray oil, azadirachtin and combination of both are presented in Table 1, 2 and 3, respectively.

Effects of pesticides on the incidence of thrips

Analysis of variance showed that all the insecticides (Table 1) recording 51.4 % to 86.6% thrips mortality including both the crops proved significantly superior to control after 1 day of treatment. The effectiveness of the treatments was decreased immediately after 3 days of spraying; however all the treatments could control the pests significantly up till 10 days of spraying. The combined treatment showed very effective result recording the highest percent mortality (82.67% and 86.6% in tomato and capsicum, respectively) which was however; at par with the agricultural spray oil in both the crops. After 3 days of application, the effectiveness of all the treatment decreased, supporting the results of Sabir *et al.* 2012. The combined treatment proved most effective throughout the treatment period

Table 1. Effect of biorational pesticides on the incidence of thrips in greenhouse tomato and capsicum.

Treatments	Conc. (%)	Tomato				Capsicum			
		Mortality (%) of thrips population after treatment * (days)				Mortality (%) of thrips population after treatment *(days)			
		1	3	7	10	1	3	7	10
Agricultural Spray oil	1	73.84^a (59.12)	45.50^b (42.42)	20.00^b (26.56)	18.72^a (24.88)	82.67^a (65.35)	56.60^a (48.79)	10.00^c (18.44)	13.33^b (21.39)
Azadirachtin	1	51.40^c (45.80)	25.60^c (30.40)	20.00^b (26.56)	15.66^a (23.26)	70.30^b (56.98)	26.66^b (31.05)	16.50^b (23.89)	5.00^c (12.92)
Agricultural spray oil + Azadirachtin	1	82.67^a (65.35)	56.60^a (48.79)	33.00^a (35.06)	19.60^a (26.28)	86.60^a (68.53)	67.33^a (55.12)	26.66^a (31.05)	14.60^a (22.46)
Control	--	2.00^d (8.13)	2.66^d (9.28)	4.33^c (11.97)	2.40^b (8.91)	3.00^c (9.98)	3 .00^c (9.98)	4.00^d (11.54)	2.00^d (8.13)
CD (P=0.05)		6.24	5.26	5.62	4.02	9.23	6.60	4.35	6.24

*Data based on mean of two sprays and eight replicates each; Figures in parentheses are arcsine transformed values; In a column; 'means' followed by a common letter do not differ significantly at $P<0.05$ by Duncan`s Multiple Range test.

followed by individual application of agricultural spray oil and azadirachtin. Earlier we also reported (Deka *et al.* 2011) effective control of two-spotted spider mite, *T. urticae* on greenhouse cucumber by combined spraying of agricultural spray oil and azadirachtin (0.5%). The petroleum oil spray residues reduced infestation of some insects by preventing oviposition and its effects depended on concentration of oil and time of spraying. Petroleum oil alone or combined with a microbial agent as emulsifier have a synergistic and less harmful effect for the environment and are recommended for use in IPM programmes (Khyami and Ateyyat, 2002).

Effects of pesticides on the incidence of Bacterial Wilt

It was observed from analysis of variance that pesticide application had significant effect on incidence of bacterial wilt disease compared to control (Table 2). The combined treatment of agricultural spray oil and azadirachtin was found to be most effective throughout the treatment period followed by treatment of agricultural spray oil and azadirachtin alone for controlling the bacterial wilt in both the crop.

Table 2. Effect of biorational pesticides on the incidence of bacterial wilt in greenhouse cultivated tomato and capsicum.

Treatments	Tomato				Capsicum			
	Bacterial Wilt Disease incidence (%) after treatment * (days)				Bacterial Wilt Disease incidence (%) after treatment * (days)			
	1	3	7	10	1	3	7	10
Agricultural spray oil	19.86^{bc} (26.42)	29.30^{b} (32.77)	33.83^{b} (35.55)	43.64^{b} (41.32)	20.00^{ab} (26.56)	24.00^{b} (29.33)	28.33^{b} (32.14)	29.00^{b} (32.58)
Azadirachtin	26.66^{ab} (31.05)	33.83^{ab} (35.55)	45.66^{a} (42.48)	69.00^{a} (56.17)	17.33^{b} (24.58)	32.00^{ab} (34.45)	30.33^{b} (30.40)	34.53^{ab} (35.97)
Agricultural spray oil + Azadirachtin	15.66^{c} (23.26)	13.33^{c} (21.39)	20.40^{c} (26.85)	26.66^{c} (31.05)	8.10^{c} (16.54)	12.33^{c} (20.53)	13.33^{c} (21.39)	17.33^{c} (24.58)
Control	36.86^{a} (37.35)	45.66^{a} (42.48)	43.00^{ab} (40.98)	42.00^{b} (40.40)	30.33^{a} (33.40)	36.06^{a} (36.87)	47.13^{a} (43.28)	45.66^{a} (42.48)
CD (P=0.05)	7.67	8.06	6.05	10.08	7.68	6.50	8.50	7.90

*Data based on mean of two sprays and eight replicates each; Figures in parentheses are arcsine transformed values; In a column, 'means' followed by a common letter do not differ significantly at P<0.05 by Duncan`s Multiple Range test.

Table 3. Effect of biorational pesticides on the incidence of root knot nematode in greenhouse cultivated tomato and capsicum.

Treatments	Tomato				Capsicum			
	Initial nematode population (per cc soil)	No. of egg mass/g root	Final nematode population in soil/ml	Root knot nematode gall index after 60 days	Initial nematode population (per cc soil)	No. of egg mass/g root	Final nematode population in soil/ml	Root knot nematode gall index after 60 days
Agricultural spray oil	9.0	9.6ab	6.7b	3.5ab	6.0	5.6ab	2.9bc	3.3ab
Azadirachtin	7.6	8.6bc	7.4b	3.2abc	5.6	4.6bc	3.4b	3.2ab
Agricultural spray oil + Azadirachtin	8.4	5.3c	3.6 c	2.3bc	6.4	3.4bc	2.0c	2.1c
Control	7.8	11.4a	10.8a	4.01a	5.8	7.4a	5.4a	3.53a
CD (P=0.05)		2.37	2.3	1.50		2.33	1.13	1.02

*Data based on mean of two sprays and eight replicates each; Figures in parentheses are arcsine transformed values; In a column, 'means' followed by a common letter do not differ significantly at P<0.05 by Duncan`s Multiple Range test.

Effects of pesticides on the incidence of Root knot nematode

The results revealed that all the treatment tested were effective against *M. incognita* (Table 3). Among the treatments the combination of agricultural spray oil and azadirachtin was found superior to the other treatments by recording lowest root knot index of 2.3 compared to 4.01 in control in tomato and 2.1 compared to 3.53 in control in capsicum. The same treatment has also recorded the lowest nematode population in soil and egg masses/g root at harvest over control in both the crops. The study emphasizes that, combination of agricultural spray oil and azadirachtin, for its properties and for the demonstrated efficacy, can be included in programs of eco-efficient production, in particular in IPM strategies that will soon open a new age in the field of nematode control.

Transcript expression profiling of tomato annexin AnnLep35

The temporal and spatial expression of genes and their sub-cellular localization of the proteins encoded by these genes provide important clues to their functions. Towards exploring molecular responses which may mediate a combination of biotic stresses in two important vegetables cultivated under protected environment, we started by carrying out a transcript expression profiling of multifunctional signaling protein annexin in a time course experiment using semi quantitative RTPCR. The nucleotide and amino acid sequences of two characterized annexins from tomato *(AnnLep35)* and capsicum *(AnnCap32)* with accession numbers AF079231 and CAA10261 respectively were downloaded from NCBI database. The sequence alignment using ClustalW2 (https://www.ebi.ac.uk/Tools/msa/clustalw2/) showed 89% homology at the amino acid level (Fig. 1). Primers were designed from homologous region of tomato and capsicum annexin to amplify a 300 bp sequence containing annexin gene specific motif using end point RTPCR from both tomato and capsicum. The isolated fragment was sequenced and confirmed as annexin from each crop respectively.

Annexin transcript expression profiles in tomato and capsicum showed similar expression in control healthy plants and differential expression pattern was observed in three stress conditions over a period of 2- 15 days of infection. The best induction of annexin transcripts in tomato was observed in insect infected sample followed by diseased samples and nematode infected sample (Fig. 2). Semi quantitative analysis of expression pattern revealed higher

```
AnnCap32   MASLTVPAHVPSAAEDCEQLRSAFKGWGTNHKLIISILAHRTAAQRKLIRQTYAETFGED 60
AnnLep35   MASLTVPAHVPSAAEDCEQLRSAFKGWGTNHKLIISILAHRTAAQRKLIRQTYAETFGED 60

                  ...........Repeat I..............
AnnCap32  LLKELDRELTHDFEKLVLVWTLDPSERDAHLKEATKRWTKSNFVLVELACTRSPKELVL  120
AnnLep35  LLKDLDELTSDFQRVVLLWTLSPAERDAYLVNEATKRLTASNWGIMEIACTRSSDDLFK  120

                      ........ Repeat II...
AnnCap32  AREAYHABYKKSLEEDVAYHTTGDHRKLLVPLVSSYRYGGEEVDLRLAKAESKILHEKIS 180
AnnLep35  ARQAYHAPYKKSLEEDVAYHTVGDPRKLLVPLITAPRYEGDEVNMTLARKGSKYLMERIS 180
AnnCap32  DKAYSDDEVIRILATRSKAQLNATLNHYKDEHGEDILKQL---DGDEPVALLRATIKGLV    238
AnnLep35  DKAYHDEEIIRIISTRSKAQLSATFNHYHDHHGHEIIKDLEADDDDEYLKLLRAAIECLK    240
                   ........Repeat III..............
AnnCap32  YPEHYFVEVLRDAINRRGTEEDHLTRVIATRAEVDLRIIADEYQKRDSIPLGRAIAKDTR    298
AnnLep35  -PREHPEKVLRLAIKKLGTDEWDLTRVVATRAEVDMERIKEEYHRRNSVTLDRAIAGDTS    299

                  ...............................Repeat IV.........
AnnCap32  GDYESMLLALLGQEED 314
AnnLep35  GDYERKLLALIGHGD- 314
```

Fig. 1. Alignment of deduced amino acid sequences of tomato and capsicum. Underlined, endonexin (typeIICa^{2+} binding) sequences repeat I to IV. Note that only repeat I and IV binding Ca^{2+} ions in plant annexins.

expression in 2 days of infection in comparison to 10 days and 15 days of infection in all the three biotic stresses (Fig. 3). Relatively, expression in all biotic stress samples was found to be relatively higher in comparison to the healthy leaf sample. In capsicum also, expression of annexin was differentially expressed and regulated under various biotic conditions. The best expression of annexin in capsicum was found to be diseased infected sample immediately followed by insect infected sample and nematode infected sample (Fig. 4 and Fig. 5). On a comparative basis, expression of annexin gene under all 3 biotic stresses was found to be increasingly induced in

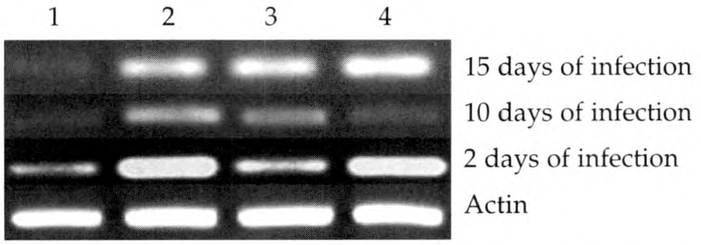

Fig. 2. Transcript expression profiling of annexin gene *AnnLep35* in 3 different days of infection under 3 biotic stress in tomato leaves as analysed by RTPCR .Lane 1: Healthy control plant; Lane 2: Insect (thrips) infected plant; Lane 3: Nematode infected plant; Lane 4: Disease (Bacterial blight) infected plant; Lower panel amplification of actin transcripts shown as equal loading and expression control

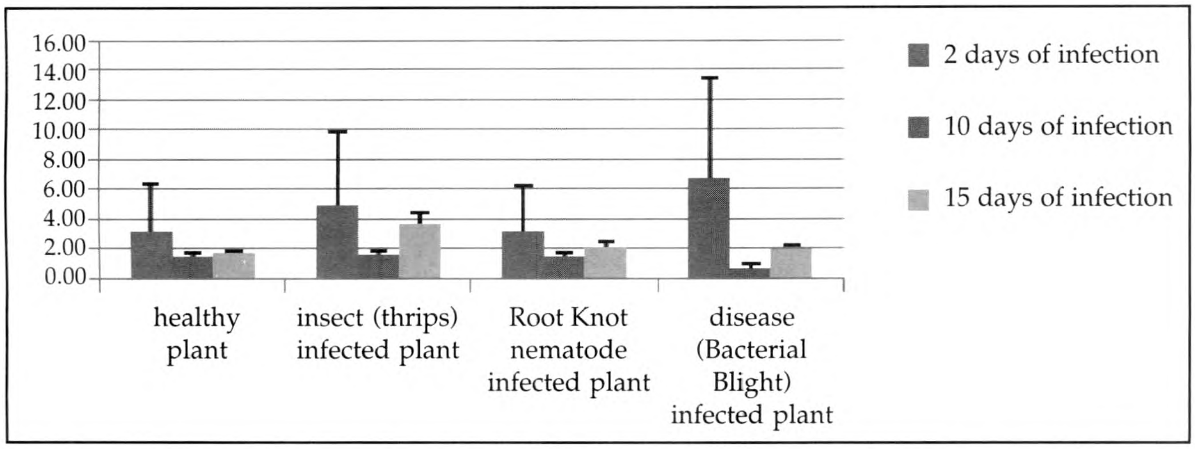

Fig. 3. Relative transcript accumulation of annexin transcripts in leaves of tomato. The relative expression values were normalized to endogenous control actin . Measurements were made on three replicates for each treatment.The error bar indicates SD of the mean.

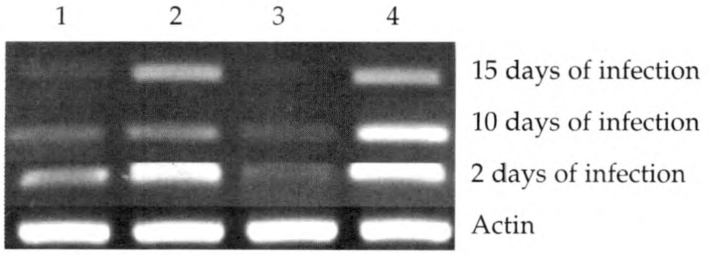

Fig. 4. Transcript expression profiling of annexin gene *AnnLep35* in 3 different days of infection under 3 biotic stress in capsicum leaves as analysed by RTPCR .Lane 1: Healthy control plant; Lane 2: Insect (thrips) infected plant; Lane 3: Nematode infected plant; Lane 4: Disease (Bacterial blight) infected plant ; Lower panel amplification of actin transcripts shown as equal loading and expression control

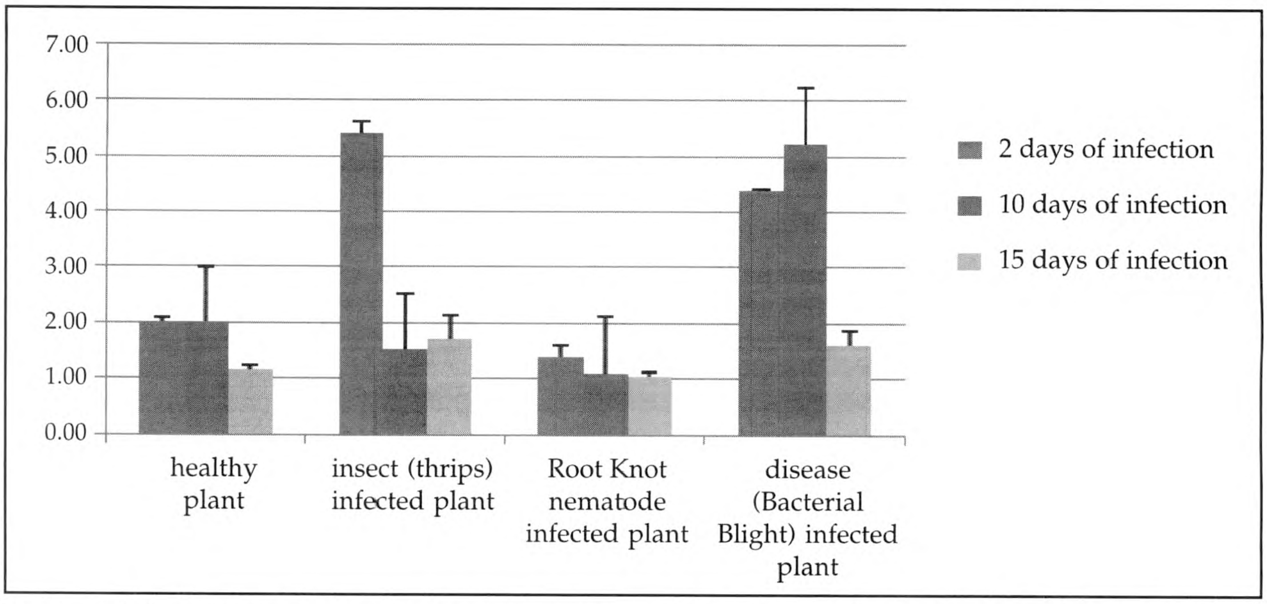

Fig. 5. Relative transcript accumulation of annexin transcripts in leaves of capscicum. The relative expression values were normalized to endogenous control actin . Measurements were made on three replicates for each treatment. The error bar indicates SD of the mean.

comparison to healthy capsicum leaf sample thus indicating positive modulation under these biotic stress conditions.

The differential induction in annexin expression patterns under various biotic stressors suggest the potential functional role for annexin in mediating adverse stimulations in tomato and capsicum under green house condition. Although we separately tested the effects of each biotic stress on annexin expression, often these individual stresses can occur together and there is cross-talk between the various stress pathways. The results presented and discussed here provide clues towards elucidating the function of annexin gene during growth and development and under adverse conditions in green house environment. Differential expression pattern collectively suggest, annexin has both distinct and overlapping function in these signal transduction pathway. Future studies in this direction using gene knockouts, over expression and other genetic studies will help reveal just how important role these proteins play in plants through Ca^{2+} signaling.

CONCLUSION

In conclusion, the use of potentiating mixtures is a practical strategy to combat insecticide resistance. This study has shown that the use of combination of azadirachtin and agricultural spray oil is the most effective component of IPM for controlling the pest of tomato and capsicum. Tomato thrips, bacterial wilt and root knot nematode are serious pests under protected cultivation in India especially in tomato and capsicum compelling farmers to opt for intensive insecticide applications which may be a cause of development of resistance to newer insecticides. We also found significantly higher message levels for annexin *AnnLep35* in all infected plants of tomato and capsicum compared to control plants, which might account for common calcium signaling mechanisms. Towards imparting resistance against various pathogen infection and further contribution to the development of disease-resistant crops that can easily fit into the IPM programs annexin shows considerable potential which requires further investigations.

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Inheritance of resistance to blast (*Magnaporthe grisea,* T.T. Hebert) in some rice (*Oryza sativa* L.) cultivars

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Abstract

The research work was undertaken at Raipur, Ambikapur and Jagdalpur district of Chhattisgarh, India, with the objectives of identifying functional resistance conferring genes in Chhattisgarh state, monitoring resistance in some genotypes/breeding lines and detecting variability in the blast population over the years, understanding the mode of inheritance of resistance to blast in some selected resistant donors. The experimental materials consisted of (a) a set of thirty one blast monogenic / differential lines along with seventy nine other genotypes including breeding lines, resistant and susceptible checks, were tested at blast 'hot spots' Ambikapur for three years (2007-2009), (b) F_1, F_2, and F_3 populations of the 28 crosses attempted for the inheritance study were screened against the blast population at Ambikapur to ascertain the genetic ratios. The inheritance investigation uncovered that blast resistance in R 1013-2307-1-1, R 1124-91-2-73, R 1518-762-3-564-1, R 1558-2423-3-1445-1 and R 1559-2425-2-1449-1 was controlled by a single dominant gene, while two independent dominant genes governed resistance in R 1519-781-5-598-1 and R 1540-1888-1278-1. The blast population in the Northern Hilly Region proved highly unpredictable and comprised of more than two highly virulent races. Breakdown of many resistant strains and genes occurred during the study, which could be attributed to changes in the frequency of pathogenic races prevailing over the years. Among the blast differential genes (monogenic lines) tested, only 'Pi-z^5' gene consistently imparted complete resistance against the blast population in the Northern Hilly Region of Chhattisgarh, Pi-z, Pi-9 and Pi-k^h provided variable level of resistance. Eight strains *viz.*, R 1518-762-3-564-1, R 1519-781-5-598-1, R 1540-1888-1278-1, R 1558-2423-3-1445-1, B 6441-FMR-6-0-0, F 7-10, IR42221-145-2-3-2 and 5173 showed consistently stable resistant reaction over the years.

Key words: Rice, Blast, Resistance, Genetics, Inheritance

Rice is the staple food for more than half of the world's population. Demand for rice continues to increase due to the ever-increasing rice consumer base. However, the present rate of increase in rice production (2000-09) has slowed down (1.21%) compared with that of previous decades (2.49%) during 1970-79 and (1.70%) in 1990-2000, due to various biotic and abiotic stresses (Khush and Jena, 2009). Among the biotic stresses, blast disease is the most devastating disease in rice cultivation by causing maximum up to 90% yield loss (Ramkumar *et al.,* 2010). It is considered as a major constraint in rice production in different rice ecosystems ranging from irrigated (40-100%) to rainfed (70%) and upland rice area (63%) in major rice growing countries of the world, except in Australia (Vera Cruz *et al.,* 2007).

With a view to manage the disease, the use of resistant cultivars with major resistance (R) genes still remains one of the most reliable methods. Identification and incorporation of different blast resistance genes with overlapping resistance spectra have long been main objectives of rice breeding program worldwide (Wang *et al.*, 2007). However, because of either the rapid evolution of new pathogen races or the selection of a rare component of the pathogen population that is already virulent, resistance is rendered ineffective in many cultivars. Thus, breeding for more durable resistant cultivars therefore has become a priority in rice improvement.

Chhattisgarh state, considered as the 'rice bowl', has 3.61 million hectare area under rice cultivation with a production of about 5.47 million tonnes (Anonymous, 2009). The prevailing environment in some areas of Chhattisgarh such as Bastar Plateau and Northern Hilly Region favors the development of blast to epidemic proportions and has been considered as "hot spots" for the blast. Severe blast (S, >50%) was recorded in plateaus of Jharkhand and Chhattisgarh (Production -oriented survey report, 1994-2006) and that was higher than the plains in the same region (Variar, 2007). Though in Chhattisgarh some rice varieties and breeding lines, as sources of blast resistance, were identified (Persuad, 2006). However, a proper understanding of this disease is of utmost importance, thus the study was carried out to identify the functional resistance conferring genes, detection of variability in the pathogen population, inheritance pattern.

MATERIALS AND METHODS

The research work was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh. Collaboration was made with College of Agriculture and Research Station Ambikapur to facilitate screening against blast. The studies were extended over a period of five cropping seasons *viz.*, wet season *(kharif)* 2007, 2008, 2009, and dry season *(rabi)* 2008, 2009. The experimental materials consisted of (a) a set of thirty one blast monogenic/differential lines along with seventy nine other genotypes including breeding lines, resistant and susceptible checks, were tested at blast 'hot spots' Ambikapur for three years (2007-2009), (b) F_1, F_2, and F_3 populations of the 28 crosses made for the inheritance study, were screened against the blast population at Ambikapur to ascertain the genetic ratios. The experiment was conducted under field conditions. All the standard agronomic practices were followed during cultivation of the crop. Screening techniques employed as Uniform Blast Nursery (UBN) test procedure (Ou, 1965). Evaluation was done about 30-35 days after seeding, when susceptible check reached 9 score, using the Standard Evaluation System (SES) based on a 0-9 scale as given by International Network for Genetic Evaluation of Rice, INGER (1996). For the genetic studies score 4 and 5 were clubbed with susceptible. In F_1 and F_2, plants were individually scored. The F_3 progenies were classified as breeding true for resistance (all plants in the line being resistant), segregating (both resistant and susceptible were observed) or breeding true for susceptibility (all plants in the line being susceptible). For the genetic studies score up-to 3 were kept as resistant while score 4 and 5 were clubbed with susceptible. The Chi-Square (χ^2) test was employed for statistical analysis to test the significance of deviation of an observed segregation ratio from a theoretical one for the purpose of working out the genetic ratios in F_2 and F_3.

RESULTS AND DISCUSSION

Rice Blast Screening

Blast monogenic lines and new rice genotypes were screened along with eight susceptible checks (Mahisugandha, Dubraj, Poornima, Danteshwari, Swarna, Mahamaya, Cheptigurmatia, and HR12) against blast population over the years 2007-2009 at Ambikapur. The primary aim was to identify effective resistance conferring blast genes in Chhattisgarh. The reaction of these genes over the years are given in Table 1. Highly susceptible reaction (score 9) was consistently observed for all eight checks over the years. This served as a benchmark for the reliability of reaction of the test entries.

Of the thirty-one monogenic lines tested at Ambikapur during *kharif* 2007 only IRBL 9, IRBL 10, IRBL 22, IRBL 31 and IRBL 8 possessing the genes *Pi-z*, *Pi-z*^{5}, *Pi-9*, *Pi-z*^{5} and *Pi-k*^{h} respectively provided resistance (score 1 & 3), while the remaining 26 lines/genes proved highly susceptible and same as the checks. During *kharif* 2008, resistant reaction was recorded for four entries *viz.,* IRBL 10, IRBL 31 (both possessing *Pi-z*^{5} gene), IRBL 22 *(Pi-9)* and IRBL 9 *(Pi-z)* (score 1 & 3), while IRBL 8 *(Pi-k*^{h}*)* was moderately resistant and all other entries highly susceptible (score 9). But only two blast monogenic lines *viz.,* IRBL 10, IRBL 31 (both possessing *Pi-z*^{5} gene) were recorded resistant reaction (score 3) and other three monogenic lines IRBL 9 *(Pi-z),* IRBL 22 *(Pi-9)* and IRBL 8 *(Pi-k*^{h}*)* were found moderately resistant (score 5) at Ambikapur during the *kharif* 2009. Thus, the *Pi-z*^{5} gene should be utilized in developing blast resistant varieties for the Chhattisgarh state. This gene is providing durable and stable resistance in the region. Identification of functional blast resistance gene (s) for a particular region is a prerequisite for their meaningful deployment (Shridhar *et al.,* 1999).

Overall, twenty nine new genotypes *viz.,* IR 64, R 1013-2307-1-1, R 1124-91-2-73, R 1250-1557-1-895-1, R 1448-578-2-473-1, R 1470-345-338-2-1, R 1518-762-3-564-1, R 1519-769-2-574-1, R 1519-778-2-590-1, R 1519-781-5-598-1, R 1519-784-1-599-1, R 1539-1785-1-1263-1, R 1540-1888-1278-1, R 1543-1966-1-1290-1, R 1551-2169-1-1354-1, R 1558-2419-2-1442-1, R 1558-2423-3-1445-1, R 1559-2425-2-1449-1, R 1559-2427-1-1450-1, R 1559-2427-2-1451-1, R 1560-2442-1-1456-1, R 1723-2271-1-1404-1, B 6441-FMR-6-0-0, F 7-10, IR 42221-145-2-3-2, 5173, Abhaya, G 95-02 and BR 240 proved to be resistant over the years (2007-09) at Ambikapur.

The Colombian cultivar 5173 has *Pi-z*^{5} gene, proved highly resistant with scores of 1 over the three years testing at Ambikapur. Also score of 1 and 3 was observed right through from 2007-2009 for monogenic lines IRBL 10 and IRBL 31 that are representatives of *Pi-z*^{5} gene and both the lines were derived from C101 A51. The reason why 5173 showed better (less) score than all these NIL's is possibly due to additional effective minor genes/QTL's that may be present in cultivar 5173 which supported the resistance of gene *Pi-z*^{5}. The same may be the case with IR42221-145-2-3-2 that possess *Pi-z*^{5} gene.

The gene present in Guyanese strains B 6441-F-MR-6-0-0 (Pi-48), F7-10 (Pi-49) were reported to be new blast resistant gene (Persaud, 2006). Both showed highly resistant score of 1, so they can be used as new donors for the blast resistant gene. F 7-10 has extra-long slender grain and high production potential. The other two Guyanese strains BR 240 and G 95-02 were also imparting resistance of variable level.

Inheritance of resistance

Twenty eight crosses were made to analyze the inheritance pattern of the genes involved in the resistant parents. The F_1, F_2, and F_3, populations of the crosses were screened against the blast population prevailing at Ambikapur for classification of the plants/progenies to fit the appropriate genetic ratios. The reactions of the various populations are presented in Table 1. Seven resistant parents *viz.,* R 1013-2307-1-1, R 1124-91-2-73, R 1518-762-3-564-1, R 1519-781-5-598-1, R 1540-1888-1278-1, R 1558-2423-3-1445-1 and R 1559-2425-2-1449-1 were crossed with four susceptible parents (HR 12, Swarna, Mahamaya and Cheptigurmatia). The F_1 populations of all the crosses showed resistance reaction against the blast population. This indicated the dominant nature of the resistance gene(s) involved. The F_2 population of the crosses of R 1013-2307-1-1, R 1124-91-2-73, R 1518-762-3-564-1, R 1558-2423-3-1445-1 and R 1559-2425-2-1449-1 with susceptible parents segregated in a frequency of three resistant plants: one susceptible plant (3R:1S). This suggested the presence of one single dominant gene in the resistant parent. Further, the F_3 progenies of these crosses for each resistant parent were analyzed. A segregation pattern of one homozygous resistant: two segregating (heterozygous): one homozygous susceptible, (1R:2Sg:1S) was observed for these crosses as expected following simple Mendelian inheritance. This confirmed the inheritance of a single dominant gene present in these resistant parents, while the segregation behavior of F_2 population of the crosses of R 1519-781-5-598-1 and R 1540-1888-1278-1 with susceptible parents fit well in fifteen resistant plants: one susceptible plant ratio (15R:1S) signifying the possibility of two independent dominant genes controlling resistance. Further, the F_3 progenies of these crosses were evaluated and classified into seven homozygous resistant: eight segregating (heterozygous): one homozygous susceptible

Table 1. Reaction of blast in Rice lines at Ambikapur.

SN	Genotypes	Designation	Target gene	Blast score & reaction				
				Ambikapur			Maximum Score	Reaction
				kh.2007	*kh.2008*	*kh.2009*		
1.	IRBL 1	IRBLa-A	*Pi-a*	9	9	9	9	S
2.	IRBL 2	IRBLa-C	*Pi-a*	9	9	9	9	S
3.	IRBL 3	IRBLi-F5	*Pi-i*	9	9	9	9	S
4.	IRBL 4	IRBLks-F5	*Pi-k*^{s}	9	9	9	9	S
5.	IRBL 5	IRBLks-S	*Pi-k*^{s}	9	9	9	9	S
6.	IRBL 6	IRBLk-ka	*Pi-k*	9	9	9	9	S
7.	IRBL 7	IRBLkp-K60	*Pi-k*^{p}	9	9	9	9	S
8.	IRBL 8	IRBLkh-K3	*Pi-k*^{h}	3	5	5	3	R
9.	IRBL 9	IRBLz-Fu	*Pi-z*	1	3	5	1	R
10.	IRBL 10	IRBLz5-CA	*Pi-z*^{5} = *Pi-2(t)*	1	1	3	1	R
11.	IRBL 11	IRBLzt-T	*Pi-zt*	9	9	9	9	S
12.	IRBL 12	IRBLta-K1	*Pi-ta* = *Pi-4(t)*	9	9	9	9	S
13.	IRBL 13	IRBLta-CT2	*Pi-ta*	9	9	9	9	S
14.	IRBL 14	IRBLb-B	*Pi-b*	9	9	9	9	S
15.	IRBL 15	IRBLt-K59	*Pi-t*	9	9	9	9	S
16.	IRBL 16	IRBLsh-S	*Pi-sh*	9	9	9	9	S
17.	IRBL 17	IRBLsh-B	*Pi-sh*	9	9	9	9	S
18.	IRBL 18	IRBL1-CL	*Pi-1*	9	9	9	9	S
19.	IRBL 19	IRBL3-CP4	*Pi-3*	9	9	9	9	S
20.	IRBL 20	IRBL5-M	*Pi-5(t)*	9	9	9	9	S
21.	IRBL 21	IRBL7-M	*Pi-7(t)*	9	9	9	9	S
22.	IRBL 22	IRBL9-W	*Pi-9*	1	3	5	1	R
23.	IRBL 23	IRBL12-M	*Pi-12(t)*	9	9	9	9	S
24.	IRBL 24	IRBL19-A	*Pi-19*	9	9	9	9	S
25.	IRBL 25	IRBLkm-Ts	*Pi-k*^{m}	9	9	9	9	S
26.	IRBL 26	IRBL20-IR24	*Pi-20*	9	9	9	9	S
27.	IRBL 27	IRBLta2-Pi	*Pi-ta*^{2}	9	9	9	9	S
28.	IRBL 28	IRBLta2-Re	*Pi-ta*^{2}	9	9	9	9	S
29.	IRBL 29	IRBLta-CP1	*Pi-ta*	9	9	9	9	S
30.	IRBL 30	IRBL11-Zh	*Pi-11(t)*	9	9	9	9	S
31.	IRBL 31	IRBLz5-CA(R)	*Pi-z*^{5}	1	1	3	1	R
32.	IR-64			1	3	3	3	R
33.	MTU 1065			7	7	7	7	S
34.	MTU 1075			7	7	9	9	S
35.	OR 1898-18			9	9	9	9	S
36.	R 714-5-55-2-1			3	5	5	5	S
37.	R 979-67-2-44-1			5	7	7	7	S
38.	R 979-1528-2-1			3	5	5	5	S
39.	R 1013-2307-1-1			1	3	3	3	R
40.	R 1022-1803-1-1			3	5	5	5	S
41.	R 1027-2238-3-1			3	5	5	5	S
42.	R 1060-30-2-41-1			3	5	5	5	S
43.	R 1124-69-1-45-1			3	5	5	5	S
44.	R 1124-91-2-73			3	3	3	3	R
45.	R 1130-80-1-52-1			3	7	7	7	S
46.	R 1207-257-5-1			3	3	5	5	S
47.	R 1219-650-2-314-1			5	7	7	7	S
48.	R 1238-692-820-1-1			3	7	7	7	S
49.	R 1238-1820-1-1			3	5	7	7	S
50.	R 1240-913-2-1031-1			3	3	7	7	S
51.	R 1240-927-3-1056-1			5	7	5	5	S
52.	R 1247-1936-1-1			1	5	5	5	S

53.	R 1248-1489-2-822-1	9	9	9	9	S
54.	R 1250-1557-1-895-1	1	3	3	3	R
55.	R 1262-1667-1-1	1	5	5	5	S
56.	R 1262-1668-2-1	1	5	5	5	S
57.	R 1264-1670-1-1	3	3	5	5	S
58.	R 1327-483-1-1	7	7	7	7	S
59.	R 1448-153-65-2-1	9	7	7	7	S
60.	R 1448-578-2-473-1	3	1	3	3	R
61.	R 1454-87-50-4-1	7	7	7	7	S
62.	R 1454-171-96-1	7	7	9	9	S
63.	R 1456-199-3-180-1	5	3	5	5	S
64.	R 1462-243-100-7-1-1	5	7	7	7	S
65.	R 1470-345-338-2-1	3	3	3	3	R
66.	R 1473-529-249-4-1	1	1	3	3	R
67.	R 1475-468-564-2-1	3	5	5	5	S
68.	R 1493-625-3-499-1	3	5	3	5	S
69.	R 1502-643-784-1-1	3	3	5	5	S
70.	R 1518-762-3-564-1	1	1	3	3	R
71.	R 1518-767-4-569-1	1	5	5	5	S
72.	R 1519-769-2-574-1	1	3	3	3	R
73.	R 1519-773-5-583-1	3	3	3	3	R
74.	R 1519-778-2-590-1	1	3	3	3	R
75.	R 1519-781-5-598-1	1	1	3	3	R
76.	R 1519-784-1-599-1	1	1	3	3	R
77.	R 1520-936-1-811-1	9	7	9	9	S
78.	R 1528-1139-3-1003-1	3	5	5	5	S
79.	R 1529-1166-1-1020-1	3	3	3	3	R
80.	R 1529-1183-1-1041-1	1	1	3	3	R
81.	R 1529-1183-3-1043-1	1	1	3	3	R
82.	R 1530-1194-2-1061-1	1	3	5	5	S
83.	R 1537-1566-1-1210-1	3	5	5	5	S
84.	R 1538-1614-1-1221-1	3	5	5	5	S
85.	R 1539-1785-1-1263-1	1	3	3	3	R
86.	R 1540-1888-1278-1	1	1	1	1	R
87.	R 1543-1966-1-1290-1	3	3	3	3	R
88.	R 1551-2169-1-1354-1	3	3	3	3	R
89.	R 1558-2419-2-1442-1	3	3	3	3	R
90.	R 1558-2423-3-1445-1	1	1	1	1	R
91.	R 1559-2425-2-1449-1	1	1	3	3	R
92.	R 1559-2427-1-1450-1	1	1	3	3	R
93.	R 1559-2427-2-1451-1	1	3	3	3	R
94.	R 1560-2442-1-1456-1	1	3	3	3	R
95.	R 1723-2271-1-1404-1	1	3	3	3	R
96.	B 6441-FMR-6-0-0	1	1	1	1	R
97.	F 7-10	1	1	1	1	R
98.	IR 42221-145-2-3-2	1	1	1	1	R
99.	5173	1	1	1	1	R
100.	Abhaya	1	3	3	3	R
101.	G 95-02	1	3	3	3	R
102.	BR 240	1	3	3	3	R
103.	Mahisugandha (ch)	9	9	9	9	S
104.	Dubraj (ch)	9	9	9	9	S
105.	Swarna (ch)	9	9	9	9	S
106.	Poornima (ch)	9	9	9	9	S
107.	HR 12 (ch)	9	9	9	9	S
108.	Mahamaya (ch)	9	9	9	9	S
109.	Cheptigurmatia (ch)	9	9	9	9	S
110.	Danteshwari (ch)	9	9	9	9	S

kh = *kharif* season, ch = Susceptible check, R=Resistant, S=Susceptible

Table 2. Reaction of F_1, F_2 and F_3 population to Magnaporthe grisea in Twenty eight crosses of rice

S N	Cross combination	F_1 Reac-tion	Reaction of F_2 plants						Reaction of F_3 progenies						
			No. of Plants			Expect-ed	χ^2	P-value	No. of progenies				Expect-ed Ratio	χ^2	P-value
			R	S	Total	R:S			R	Sg	S	Total	R:Sg:S		
1.	R 1013-2307-1-1 x Swarna	R	331	94	425	3:1	1.883	0.20-0.10	29	63	39	131	1:2:1	1.718	0.50-0.30
2.	R 1013-2307-1-1 x HR 12	R	287	78	365	3:1	2.565	0.20-0.10	37	62	26	125	1:2:1	1.944	0.50-0.30
3.	R 1013-2307-1-1 x Mahamaya	R	315	113	428	3:1	0.449	0.50-0.30	41	72	33	146	1:2:1	0.904	0.70-0.50
4.	R 1013-2307-1-1 x Cheptigurmatia	R	362	114	476	3:1	0.280	0.70-0.50	35	78	41	154	1:2:1	0.494	0.80-0.70
5.	R 1124-91-2-73 x Swarna	R	405	118	523	3:1	1.658	0.20-0.10	37	71	30	138	1:2:1	0.826	0.70-0.50
6.	R 1124-91-2-73 x HR 12	R	253	102	355	3:1	2.638	0.20-0.10	35	68	26	129	1:2:1	1.636	0.50-0.30
7.	R 1124-91-2-73 x Mahamaya	R	288	81	369	3:1	1.829	0.20-0.10	29	77	35	141	1:2:1	1.709	0.50-0.30
8.	R 1124-91-2-73 x Cheptigurmatia	R	262	86	348	3:1	0.015	0.95-0.90	37	80	35	152	1:2:1	0.474	0.80-0.70
9.	R 1518-762-3-564-1 x Swarna	R	322	90	412	3:1	2.188	0.20-0.10	26	59	23	108	1:2:1	1.093	0.70-0.50
10.	R 1518-762-3-564-1 x HR 12	R	299	104	403	3:1	0.140	0.80-0.70	24	59	32	115	1:2:1	1.191	0.70-0.50
11.	R 1518-762-3-564-1 x Mahamaya	R	313	95	408	3:1	0.641	0.50-0.30	31	79	32	142	1:2:1	1.817	0.50-0.30
12.	R 1518-762-3-564-1 x Cheptigurmatia	R	280	79	359	3:1	1.717	0.20-0.10	29	58	22	109	1:2:1	1.349	0.70-0.50
13.	R 1519-781-5-598-1 x Swarna	R	352	24	376	15:1	0.011	0.95-0.90	49	53	8	110	7:8:1	0.273	0.90-0.80
14.	R 1519-781-5-598-1 x HR 12	R	372	17	389	15:1	2.346	0.20-0.10	58	78	7	143	7:8:1	1.344	0.70-0.50
15.	R 1519-781-5-598-1 x Mahamaya	R	369	27	396	15:1	0.218	0.70-0.50	48	58	6	112	7:8:1	0.235	0.90-0.80
16.	R 1519-781-5-598-1 x Cheptigurmatia	R	345	21	366	15:1	0.164	0.70-0.50	47	55	7	109	7:8:1	0.020	0.99-0.98
17.	R 1540-1888-1278-1 x Swarna	R	371	32	403	15:1	1.965	0.20-0.10	53	67	6	126	7:8:1	0.782	0.70-0.50
18.	R 1540-1888-1278-1 x HR 12	R	470	41	511	15:1	2.743	0.10-0.05	60	78	7	145	7:8:1	1.073	0.70-0.50
19.	R 1540-1888-1278-1 x Mahamaya	R	443	33	476	15:1	0.379	0.70-0.50	58	75	8	141	7:8:1	0.583	0.80-0.70
20.	R 1540-1888-1278-1 x Cheptigurmatia	R	433	22	455	15:1	1.554	0.30-0.20	60	66	8	134	7:8:1	0.064	0.98-0.95
21.	R 1558-2423-3-1445-1 x Swarna	R	328	106	434	3:1	0.077	0.80-0.70	33	73	30	136	1:2:1	0.868	0.70-0.50
22.	R 1558-2423-3-1445-1 x HR 12	R	281	75	356	3:1	2.936	0.10-0.05	33	76	25	134	1:2:1	3.373	0.20-0.10
23.	R 1558-2423-3-1445-1 x Mahamaya	R	294	104	398	3:1	0.271	0.70-0.50	34	70	28	132	1:2:1	1.030	0.70-0.50
24.	R 1558-2423-3-1445-1 x Cheptigurmatia	R	263	84	347	3:1	0.116	0.80-0.70	32	81	35	148	1:2:1	1.446	0.50-0.30
25.	R 1559-2425-2-1449-1 x Swarna	R	265	75	340	3:1	1.569	0.30-0.20	28	62	22	112	1:2:1	1.929	0.50-0.30
26.	R 1559-2425-2- 1449-1 x HR 12	R	290	79	369	3:1	2.537	0.20-0.10	33	78	28	139	1:2:1	2.439	0.30-0.20
27.	R 1559-2425-2- 1449-1 x Mahamaya	R	298	103	401	3:1	0.101	0.80-0.70	38	69	30	137	1:2:1	0.942	0.70-0.50-
28.	R 1559-2425-2-1449-1 x Cheptigurmatia	R	275	109	384	3:1	2.347	0.10-0.05	36	68	31	135	1:2:1	0.378	0.90-0.80

In F_2: R = Resistant, S = Susceptible. In F_3: R = Breeding true for resistance, Sg = Segregating, S = Breeding true for susceptibility.

(7R:8Sg:1S) ratio ratifying the existence of two independent dominant genes in these resistant parents (Table 2).

Resistant parents R 1013-2307-1-1, R 1124-91-2-73, R 1518-762-3-564-1, R 1558-2423-3-1445-1 and R 1559-2425-2-1449-1 possess only one gene for resistance which is dominant. In many of the earlier studies resistance has been reported to be governed by one dominant gene (Persaud, 2002; Persaud 2006; Nagaty *et al.*, 2007 and many others, although resistance to blast has also been reported to be controlled by recessive genes (Marchetti *et al.*, 1987).

The strains R 1519-781-5-598-1 and R 1540-1888-1278-1 have two dominant genes for resistance. Resistance to blast has been noted by several workers to be governed by two dominant genes (Persaud, 2002; Persaud 2006 and Nagaty *et al.*, 2007). Even three dominant genes have been found to control resistance (Zhoa *et al.*, 1998).

Control of a trait by a dominant gene is considered to be an advantage to the breeder as it makes identification of the resistant plants easier, which is also expressed, in heterozygous condition. In-depth understanding of the inheritance of the resistance gene greatly enhances the breeder's ability to plan an appropriate breeding strategy to exploit / transfer the target gene(s). Since, the resistance genes in the parents studied are inherited independently they are expected to be transferred quite easily.

This study was intended in developing a understanding of the mode of inheritance resistance conferring genes for blast in donors in Chhattisgarh along with the functional resistance genes for the region are identified, the variation in the fungus population has been detected. This study would enable the breeders and pathologist to have a greater insight into the nature of the genetic interactions between the blast fungus and its host. The stability of resistance conferring genes in given rice cultivar is determined by how the blast pathogen changes and the way the resistance is deployed. Thus the ability of the breeders to develop varieties with effective durable blast resistance for the region is likely to be enhanced with the results obtained in this study.

From the above study one can conclude that only '*Pi-z*^{5}' gene consistently imparted complete resistance against the blast population in the Northern Hilly Region of Chhattisgarh while gene *Pi-z*, *Pi-9* and *Pi-k*^{h} provided variable level of resistance. Eight strains *viz.*, R 1518-762-3-564-1, R 1519-781-5-598-1, R 1540-1888-1278-1, R 1558-2423-3-1445-1, B 6441-FMR-6-0-0, F 7-10, IR42221-145-2-3-2 and 5173 showed consistently stable resistant reaction over the years. New resistant parents R 1013-2307-1-1, R 1124-91-2-73, R 1518-762-3-564-1, R 1558-2423-3-1445-1 and R 1559-2425-2-1449-1 possess only one dominant gene for resistance against blast whereas, strains R 1519-781-5-598-1 and R 1540-1888-1278-1 have two dominant genes for resistance.

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Disease management in Indian mustard *(Brassica juncea)* through integrated approaches

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ABSTRACT

Field experiments were conducted during *Rabi* 2010-11 to 2012-13 to manage the prevailing fungal diseases of Indian mustard through integrated approach. Removal of three lower leaves followed by foliar spray of metalaxyl 8% + mancozeb 64% WP @ 2 g l^{-1} of water was found best in controlling the white rust (12.2%). Lowest Alternaria blight (6.1%) was recorded with seed treatment followed by one foliar spray of propiconazole 25 EC @ 1 ml kg^{-1} seed and 1 ml l^{-1} of water, respectively. Significant ($P \leq 0.05$) reduction in stem rot incidence (0.6%), maximum average production (2988 kg ha^{-1}), maximum net profit as well as the incremental cost-benefit ratio (ICBR) was observed with seed treatment of carbendazim 50 WP @ 2 g kg^{-1} seed followed by two foliar spray of carbendazim 12% + mancozeb 63% WP at 2 g l^{-1} of water.

Key words: Mustard, White rust, Alternaria blight, Stem rot, Management.

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India holds a leading position in area and production of rapeseed-mustard *i.e.*, 6.34 million hectares and 7.82 million tonnes, respectively with an average productivity of 1234 kg ha^{-1}. Among Rapeseed-Mustard, Indian mustard [*Brassica juncea* (L.) Czern & Coss] contributes major share and is grown in various regions of India. Rajasthan is a leading state, both in area and production (2.83 million hectares and 3.65 million tones, respectively) of Rapeseed-Mustard crop in India with an average productivity of 1290 kg ha^{-1}. (Anonymous, 2013). Indian Mustard is ravaged by several fungal diseases *viz*., Alternaria blight [*Alternaria brassicae* (Berk.) Sacc.], white rust [*Albugo candida* (Pers. Ex Lev.) Kuntze], powdery mildew [*Erysiphe cruciferarum* (Opiz. ex Junell)] and Sclerotinia rot (*Sclerotinia sclerotiorum* (Lib.) de Bary). Seed yield loss up to 36.88 per cent in mustard due to white rust and Alternaria blight was reported by Bal and Kumar (2014). White rust caused by *A. candida* is an important disease effecting mustard crop in India. The pathogen can infect all above ground plant parts and causes yield loss up to 60 per cent (Kumar *et al*., 2008; Meena *et al*., 2002). Up to 50 per cent yield losses due to Alternaria blight have been reported in mustard from various parts of India (Meena *et al*., 2010; Kumar *et al*., 2014). Stem rot is gaining importance in the mustard growing areas during the last decade, which may cause crop failure as up to 73.8 per cent disease incidence was recorded in Rajasthan, Punjab and Haryana (Ghasolia *et al*., 2004; Bairwa, 2012). Management of these diseases by fungicides with varying degree of success has earlier been reported (Shivpuri and Gupta, 2001; Khan, *et al*., 2007). Ideally, a chemical compound should not only be safe to the human beings and other mammals, but also to the microbes. With the growing awareness of harmful effects of pesticides, use of disease tolerant cultivar, crop rotation or sanitation practices, bio- agents, plant extracts to integrate with less fungicidal spray is gaining importance in recent years. The concept of integrated disease management leads to minimize the use of fungicides with eco-friendly and sustainable management of the diseases. However, little efforts have been made on integration of cultural, biological and chemical control to manage Rapeseed-Mustard diseases. Present study was undertaken to find out better disease management strategy through integration of cultural, biological and chemical control measures to minimize the yield losses.

MATERIALS AND METHODS

Field experiments were conducted during rabi season of 2010-11 to 2012-13 at the research farm of Agricultural Research Station, Sriganganagar (S.K.R.A.U.) for management of major Rapeseed-Mustard diseases (white rust, Alternaria blight and stem rot) in a randomized block design with three replications using susceptible cultivar 'Varuna (T-59)' in 5 m × 3 m plot size with row to row spacing 45 cm and plant to plant 10 cm. Recommended doses of N P K were applied. Crop was sown in the last week of October. The crop was irrigated thrice at different developmental stages *i.e.* vegetative, flowering, and pod formation and weeding was done as and when required. Different treatment combinations (Table-1) were applied and an untreated control plot was also maintained. Foliar spray of fungicide was done at 60 and 75 days after sowing (DAS).

Observation on percent severity of white rust and Alternaria blight was recorded on leaves and pods. Observations on leaves were made on 25 randomly selected plants at 90 DAS or maximum disease pressure and observation of Alternaria blight on pods and staghead formation in white rust was recorded 15 days before harvest. The severity of the Alternaria blight was assessed using a modified 0 - 9 scale (Conn *et al.*, 1990) and same scale was used for White rust.

- 0 (Immune for WR) = No lesion.
- 1 (HR) = Non-sporulating pinpoint size or small brown necrotic spots, less than 5% leaf area covered by lesion.
- 3 (R) = Small roundish slightly sporulating larger brown necrotic spots, about 1-2 mm in diameter with a distinct margin or yellow halo, 5-10% leaf area covered by lesions.
- 5 (MR) = Moderately sporulating, non-coalescing larger brown spots, about 2-4 mm in diameter with a distinct margin or yellow halo, 11-25% leaf area covered by the spots.
- 7 (S) = Moderately sporulating, coalescing larger brown spots about 4-5 mm in diameter, 26-50% leaf area covered by the lesions.
- 9 (HS) = Profusely sporulating, rapidly coalescing brown to black spots measuring more than 6mm diameter without margins covering more than 50% leaf area.

Average severity score =

$$\frac{(N\text{-}1\times0) + (N\text{-}2\times1) + (N\text{-}3\times3) + (N\text{-}4\times5) + (N\text{-}5\times7) + (N\text{-}6\times9)}{\text{Number of leaf sample}}$$

The disease indices were calculated by using McKinney (1923) formula :

Disease index (%) =

$$\frac{(N\text{-}1\times0) + (N\text{-}2\times1) + (N\text{-}3\times3) + (N\text{-}4\times5) + (N\text{-}5\times7) + (N\text{-}6\times9)}{\text{Number of leaf sample}\times 9}\times 100$$

where, N-1 to N-6 represents frequency of leaves in the respective score.

To assess the Sclerotinia rot incidence, the plant showing even a minute lesion of stem rot symptom was considered as diseased plant. The disease incidence was calculated by counting the diseased and total number of plants per plot as per given formula :

Disease incidence (%) =

$$\frac{\text{Number of disease plants}}{\text{Total number of plants}}\times 100$$

The yield of each plot was recorded after threshing. The percent increase in yield over the control, net profit from additional yield and the economics of the additional treatments were also calculated (Incremental Cost Benefit Ratio). Data were analyzed using arc sin transformation using single factor analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Data presented in table 1 to 3 revealed that all the treatments significantly controlled white rust, Alternaria blight and Sclerotinia stem rot severity and increased the seed yield over control. Removal of three lower leaves followed by foliar spray of metalaxyl 8% + mancozeb 64% WP (0.2%) was found most effective against leaf infection of white rust followed by seed treated with carbendazim 50WP (2 gm kg^{-1} seed) + two spays of carbendazim 12% + mancozeb 63% WP (0.2%) and soil application of $ZnSO_4$ (15 kg ha^{-1}), borax (10 kg ha^{-1}) and sulphur (40 kg ha^{-1}) + two sprays of carbendazim 12% + mancozeb 63% WP (0.2%). However, seed treated with carbendazim 50 WP (2 gm kg^{-1} seed) + two spays of carbendazim 12% + mancozeb 63% WP (0.2%) was *at par* to soil application of $ZnSO_4$ (15 kg ha^{-1}) + borax (10 kg ha–1) + 5 (40 kg ha^{-1}) as based dose + 2 FS of carbondozim 12% + Moncozeb 63% (0.2%). All the treatments, where chemical fungicides and bio-control agents were used, either as seed treatment or foliar spray, significantly reduced the staghead formation of white rust (Table 1). However, no significant difference was observed among the treatments. This might be either due to the effect of fungicides on growth and sporulation of the fungus or due to increased systemic resistance in the plant due

Table 1. Per cent disease intensity (PDI) of White rust in Indian mustard (2010-11 to 2012-13).

Treatment*	2010-11		2011-12		2012-13		Mean	
	leaf stage	Stag head	leaf stage	Stag head	leaf stage	Stag head	leaf stage	Stag head
T_1	32.5 (34.7)**	2.4 (8.9)	34.0 (35.7)	2.8 (9.7)	37.0 (37.46)	2.7 (9.38)	34.5 (35.96)	2.6 (9.34)
T_2	36.1 (36.9)	4.8 (12.7)	38.6 (38.4)	4.5 (12.2)	48.1 (43.92)	2.5 (9.03)	40.9 (39.76)	3.9 (11.43)
T_3	44.2 (41.7)	3.7 (11.0)	47.0 (43.3)	4.2 (11.8)	43.7 (41.35)	2.7 (9.41)	45.0 (42.09)	3.5 (10.83)
T_4	18.9 (25.8)	1.1 (6.0)	20.7 (27.1)	2.8 (9.6)	27.4 (31.53)	1.8 (7.77)	22.3 (28.19)	1.9 (7.92)
T_5	20.9 (27.2)	3.0 (9.9)	22.9 (28.6)	3.5 (10.7)	29.6 (32.96)	1.2 (6.35)	24.5 (29.63)	2.6 (9.22)
T_6	34.0 (35.7)	3.3 (10.5)	34.0 (35.7)	3.6 (10.9)	43.0 (40.93)	3.7 (11.10)	37.0 (37.45)	3.5 (10.83)
T_7	10.6 (18.9)	2.4 (8.8)	12.8 (20.9)	3.0 (10.0)	13.3 (21.36)	0.8 (5.20)	12.2 (20.46)	2.1 (8.26)
T_8	41.7 (40.2)	2.9 (9.7)	43.7 (41.3)	3.0 (10.0)	35.6 (36.53)	3.3 (10.47)	40.3 (39.41)	3.1 (10.08)
T_9	42.8 (40.8)	3.6 (10.8)	43.7 (41.3)	3.8 (11.2)	46.7 (43.07)	1.7 (7.46)	44.4 (41.77)	3.0 (10.03)
Control	54.4 (47.5)	6.5 (14.8)	53.6 (47.1)	6.6 (14.9)	55.6 (48.17)	7.5 (15.93)	54.5 (47.58)	6.9 (15.19)
CD (P=0.05)	2.3	2.2	2.6	2.0	3.7	1.3	2.9	1.8

*T_1: seed treatment (ST) with *Trichoderma harzianum* (10 g kg^{-1}) + 1 foliar spray (FS) of *Pseudomonas fluorescence* (oil based) (10 ml lit^{-1} water) at the flower initiation stage, T_2: Soil Application (SA) of $ZnSO_4$ (15 kg ha^{-1}) + SA of borax (10 kg ha^{-1}) + S (40 kg ha^{-1}) as basal dose, T_3: removal of three lower leaves at vegetative stage, T_4: ST with carbendazim 50 WP @ 2 g kg^{-1} seed + 2 FS of carbendazim 12% + mancozeb 63% @ 0.2%, T_5: SA of $ZnSO_4$ (15 kg ha^{-1}) + SA of borax (10 kg ha^{-1}) + S (40 kg ha^{-1}) as basal dose + 2 FS of carbendazim 12% + mancozeb 63% @ 0.2%, T_6: SA of $ZnSO_4$ (15 kg ha^{-1}) + SA of borax (10 kg ha^{-1}) + S (40 kg ha^{-1}) as basal dose + 1 FS of *P. fluorescence* (10 ml lit^{-1}. water), T_7: removal of three lower leaves + 1 FS of metalaxyl 8% + mancozeb 64% @ 0.2%, T_8 : ST with carbendazim 50 WP @ 2 g kg^{-1} seed followed by removal of three lower leaves, T_9 : ST with propiconazole 25EC @ 1ml kg^{-1} seed followed by its 1 FS @ 0.1%, **Arc sine transformed values in parentheses.

to bio-control agent particularly *P. fluorescence.* These findings are in accordance with the reports of Meena *et al.*, (2002), Singh and Singh (2006) and Biswas *et al.*, (2007). Meena *et al.*, (2011a) reported fungicidal seed treatment with matelaxyl followed by foliar spray of Ridomil MZ 72 WP was most effective against white rust.

The minimum Alternaria leaf (6.1%) and pod blight (17.2%) was observed with seed treatment of propiconazole 25EC (1 ml kg^{-1}) + foliar spray of propiconazole 25EC (0.1%) followed by soil application of ZnSO$_4$, borax and sulphur + two foliar sprays of carbendazim12% + mancozeb 63% WP (0.2%) and seed treatment of carbendazim 50 WP (2 g kg^{-1} seed) + 2 foliar sprays of carbendazim12% + mancozeb 63% WP (0.2%) which were *at par* in their efficacy (Table 2). Efficacy of propiconazole 25 EC against Alternaria blight in mustard has already been reported by Singh *et al.* (2013). Soil application of minerals like sulphur, borex and zinc sulphate were found effective in the management of Alternaria blight (Meena *et al.*, 2011 b). Some earlier findings indicate the possibility of biological management of Alternaria blight of *Brassicas*, where, foliar application of native isolates of *T. harzianum* and *P fluorescens* (Meena *et al.*, 2004, 2008, 2011 b) were found effective.

Data shown in table 3 reveals that seed treatment of carbendazim 50 WP (2 g kg^{-1} seed) + 2 foliar sprays of carbendazim12% + mancozeb 63% WP (0.2%) was most effective in controlling the Sclerotinia rot incidence followed by seed treatment of propiconazole 25EC (1 ml kg^{-1}) + foliar spray of propiconazole 25EC (0.1%) and soil application of ZnSO$_4$, borax and sulphur + two foliar sprays of carbendazim12% + mancozeb 63% WP (0.2%). Seed treatment with *T. harzianum* followed by foliar spray of *P. fluorescens* at flower initiation stage was also found effective in controlling Sclerotinia rot and was *at par* to the best treatment. Bairwa (2012) reported seed

Table 2. Per cent disease intensity (PDI) of Alternaria blight in Indian mustard (2010-11 to 2012-13).

Treatment*	2010-11		2011-12		2012-13		Mean	
	leaf stage	Pod Stage	leaf stage	Pod Stage	leaf stage	Pod Stage	leaf stage	Pod Stage
T$_1$	12.2 (20.4)**	50.3 (45.2)	6.2 (14.4)	6.2 (14.4)	11.5 (19.79)	12.2 (20.44)	10.0 (18.40)	22.9 (28.58)
T$_2$	20.4 (26.9)	54.0 (47.3)	9.7 (18.1)	8.5 (17.0)	12.2 (20.44)	14.4 (22.32)	14.1 (22.05)	25.6 (30.41)
T$_3$	21.8 (27.8)	54.8 (47.7)	10.4 (18.8)	12.1 (20.4)	18.5 (25.46)	17.8 (24.92)	16.9 (24.26)	28.2 (32.08)
T$_4$	8.5 (17.0)	47.4 (43.5)	5.3 (13.3)	4.4 (12.1)	15.9 (23.49)	15.2 (22.92)	9.9 (18.33)	22.3 (28.19)
T$_5$	12.6 (20.7)	51.1 (45.6)	6.7 (14.9)	6.3 (14.5)	9.6 (18.06)	10.4 (18.77)	9.6 (18.07)	22.6 (28.37)
T$_6$	18.9 (25.8)	54.0 (47.3)	8.3 (16.7)	10.9 (19.3)	14.1 (22.00)	11.5 (19.79)	13.8 (21.77)	25.5 (30.30)
T$_7$	15.5 (23.2)	51.1 (45.6)	8.2 (16.6)	6.8 (15.1)	17.4 (24.57)	23.7 (29.12)	13.7 (21.72)	27.2 (31.42)
T$_8$	16.3 (23.8)	52.5 (46.5)	8.4 (16.9)	6.9 (15.3)	25.6 (30.35)	22.6 (28.36)	16.8 (24.16)	27.3 (31.51)
T$_9$	6.3 (14.6)	43.3 (41.1)	5.2 (13.2)	2.8 (9.7)	6.7 (14.92)	5.6 (13.58)	6.1 (14.25)	17.2 (24.52)
Control	25.7 (30.5)	57.0 (49.0)	12.8 (20.9)	13.3 (21.4)	33.7 (35.46)	28.9 (32.49)	24.1 (29.37)	33.1 (35.09)
CD (P=0.05)	1.4	2.4	1.1	1.7	2.5	1.7	1.6	1.9

*As per table 1, **Arc sine transformed values in parentheses.

treatment with carbendazim 50WP and foliar application of carbendazim12% + mancozeb 63% significantly reduced the Sclerotinia stem rot in Indian mustard. Reduction in stem rot (*S. sclerotiorum)* by use of soil amendments including sulphur has already been reported by many workers (Bairwa, 2012). Integration of cultural, biological and chemical control measures in mustard crop to reduce the losses caused by different diseases has already been reported by Singh and Singh, (2006), Khan *et al.*, (2007), Biswas *et al.*, (2007), Kumar (2009) and Gaur *et al.* (2012).

In the present investigation significantly higher seed yield 2988 kg ha^{-1} and the highest incremental cost benefit ratio (ICBR) was obtained with seed treatment of carbendazim 50 WP (2 g kg^{-1} seed) + 2 foliar sprays of carbendazim 12% + mancozeb 63% WP (0.2%) replace by which was *at par* with removal of three lower leaves followed by foliar spray of metalaxyl 8% + mancozeb 64% WP at 0.2 per cent (2984 kg ha^{-1}). However, slightly lower ICBR was observed in lower leaf removal treatments due to involvement of labour cost (Table 3). These results were corroborated by the finding of earlier workers, who reported some similar variations (Mathur and Shekhawat, 1986). The higher per rupee returns was also reported by Sharma *et al.*, (2013) in integrated disease management as compare to non-integrated disease management cultivation practice in mustard.

On the basis of results it was concluded that seed treatment with carbendazim 50 WP at 2 g kg^{-1} seed followed by two sprayings of carbendazim12% + mancozeb 63% mixture (0.2%) and removal of three lower leaves followed by foliar spray of metalaxyl 8% + mancozeb 64% WP (0.2%) minimizes the major diseases and maximized the yield of mustard.

Table 3. Per cent disease incidence of stem rot and yield of Indian mustard (2010-11 to 2012-13).

Treatment*	Stem rot (%)			Mean	Yield kg ha^{-1}			Mean	Incremental B:C
	2010-11	2011-12	2012-13		2010-11	2011-12	2012-13		
T_1	3.5 (10.7)**	0.7 (4.8)	1.6 (7.33)	1.9 (7.99)	2800	3298	2200	2766	4.0
T_2	9.5 (17.9)	1.0 (5.7)	2.7 (9.42)	4.4 (12.10)	2607	2787	2190	2528	0.7
T_3	10.5 (18.9)	1.1 (5.9)	2.2 (8.46)	4.6 (12.38)	2427	2631	2052	2370	2.5
T_4	0.8 (5.1)	0.4 (3.5)	0.6 (4.27)	0.6 (4.44)	3100	3489	2375	2988	9.5
T_5	3.3 (10.4)	0.6 (4.3)	1.5 (6.96)	1.8 (7.71)	2929	3369	2417	2905	1.2
T_6	5.6 (13.7)	0.7 (4.9)	2.5 (9.06)	2.9 (9.86)	2755	3276	2267	2766	0.9
T_7	6.9 (15.2)	0.8 (4.8)	2.1 (8.31)	3.3 (10.41)	3011	3467	2474	2984	7.5
T_8	8.8 (17.2)	1.0 (5.6)	2.6 (9.27)	4.1 (11.73)	2611	3142	2222	2658	5.5
T_9	1.8 (7.7)	0.5 (3.9)	2.0 (8.06)	1.4 (6.87)	2685	3253	2254	2731	7.2
Control	14.2 (22.1)	1.7 (7.5)	3.7 (11.09)	6.5 (14.80)	2067	2409	1968	2148	-
CD (P=0.05)	1.5	1.9	1.3	1.6	180	340	285	268	-

*As per table 1, **Arc sine transformed values in parentheses.

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Performance of System of Wheat Intensification (SWI) and conventional wheat sowing under North Eastern Plain Zone of India

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ABSTRACT

A field experiment was conducted during the *rabi* seasons of 2011-12 and 2012-13 at Regional Station Indian Agricultural Research Institute, Pusa, Samastipur, Bihar. System of wheat intensification (SWI) with different plant geometry was compared with conventional line sowing method of wheat under sandy loam soil. Seed treatment comprises of treated and untreated seed were allocated in main plot whereas three plant geometry of SWI (10 × 10, 15 × 15 and 20 × 20 cm) and one conventional line sowing at 22.5 cm were allocated in sub-plot under split plot design with three replications. Treated seed gave relatively higher effective tillers, number of grains and 1000-grain weight of wheat as compared to untreated seed. SWI at 10 cm × 10 cm recorded significantly higher effective tillers (345.7 and 405.8 m^{-2}) as compared to SWI at 15 cm × 15 cm or 20 cm × 20 cm spacing during both the years. SWI at 10 cm × 10 cm spacing recorded significantly higher grain yield (6.60 and 5.14 t ha^{-1}) during 2011-12 and 2012-13, respectively over other treatments. Irrigation water productivity was highest in SWI method with 10 cm × 10 cm spacing (27.50 and 21.42 kg $ha.mm^{-1}$) as compared to conventional line sowing (20.2 and 15. 8 kg $ha.mm^{-1}$) in 2011-12 and 2012-13, respectively. Thus, there was water saving of 17.3 and 17.8% during 2011-12 and 2012-13, respectively in SWI method of wheat sowing as compared to conventional line sowing.

Key words: SWI, conventional line sowing, seed treatment, irrigation water saving and irrigation water productivity.

Wheat is the most important cereal food grain crop of the world. Among wheat cultivating countries India has the largest area and second largest production of world after China. In the year 2011-12 and 2012-13, India has cultivated wheat on an area of 29.9 and 30.0 million hectares with total production of 94.9 and 93.5 million tonnes and productivity of 3177 and 3117 kg ha^{-1}, respectively (Agricultural Statistics at a Glance, 2014). Wheat contributes most towards public distribution system (PDS) and has become a backbone of country's food security (Prasad and Gupta, 2012). The productivity of wheat in India varies from NWPZ to NEPZ. Out of major wheat growing states of India, states likes Punjab, Haryana and Western U.P contributes with higher productivity whereas states likes Bihar, West Bengal and Odisha stands far behind. The causes of low productivity in these states is governed by so many factors like, weather (low and high temperature stress, high RH and drought), soil factors (soil texture, soil pH, EC and available nutrients), availability of inputs like quality seed, irrigation, fertilizers and technologies of production being followed. From last one decade small and marginal farmers are facing difficulties in coping with the high demand of costly inputs to meet the requirement of recommended technologies for increasing production of major cereal crops. Inspired by the success of SRI method in rice crop for compensating high yield with less inputs like seed, fertilizers and water, SWI method was initiated in India, Africa and Nepal by some community workers on fields of small and marginal farmers in 2006, and their encouraging results paved the path of systematic research among farmers, Govt. agencies and research workers in India. In the same line SWI testing in wheat was started by All India Co-ordinated Research Project of Wheat and Barley in 2010-11 and slowly it is spreading to the research scientists of agricultural universities and institutes. However, sufficient data and results with authentic conclusions are lacking with research workers. Keeping above points in view the present study was conducted for comparison of system of wheat intensification (SWI) with conventional line sowing of wheat.

MATERIALS AND METHODS

A field experiment was conducted during the *rabi* seasons of 2011-12 and 2012-13 at research farm of Regional Station, Indian Agricultural Research Institute, Pusa, Samastipur, Bihar. The soil of experimental field was sandy loam with pH 8.5 and 8.7, respectively. The soil was low in organic carbon (0.38% and 0.42%), medium in available phosphorus (19.22 and 19.80 kg ha^{-1}) and available potassium (185 and 197 kg ha^{-1}), respectively. The experiment was conducted in SPD allocated 2 seed treatment method in main plot and 3 SWI spacing (10×10, 15×15 and 20×20 cm) and one conventional line sowing (22.5 cm) in sub plots and replicated thrice. Seed were treated using 60°C hot water and dipping the seed @ 2 litre of water for 1 kg of wheat seed. After pouring the seed were stirred and floating seeds were removed.

Then 400 ml cow (indigenous) urine, 225 g vermicompost and 110 g of jaggery were added per litre of water and thoroughly mixed with seed containing water. The mixture was left for 6-8 hours and then filtered. The filtered seeds were treated with bavistin 2.5 g kg^{-1} seed and kept in wet jute bag for 8-10 hours. The seeds were dried in shade for half an hour just before sowing to facilitate easy sowing of seeds. Field was prepared with two disking followed by use of cultivator twice. Planking was done after each cultivation. In SWI method seeds of wheat were sown at square marked distance as per treatments. Conventional wheat sowing was done in line at 22.5 cm. Irrigated normal sown and medium height wheat varieties used for experimentation were DBW 39 and Raj 4229 in 2011-12 and 2012-13, respectively.

Six irrigations were applied in SWI treatments scheduled as first irrigation at 15 DAS (days after sowing), followed by 5 irrigations at 25, 40, 65, 85 and 105 DAS during both the years. While in conventional line sowing method total 5 irrigations were given at 20, 40, 60, 80 and 100 DAS. Water management varied in different planting methods of wheat. In conventional line sowing of wheat, 6 cm depth of water was maintained for all irrigations of crop starting from crown root initiation (CRI) to the physiological maturity of crop. However in SWI, 4 cm water was applied and alternate wetting and drying conditions were maintained throughout the cropping season to keep the soil moist but unsaturated. The mean depth of irrigation water in each plot was measured at 10 selected spots after irrigations with the scale having mm mark. Total rainfall received during *rabi*, 2011-12 and 2012-13 were 47.5 and 36.6 mm, respectively. Above rainfall data were recorded at the meteorological observatory of IARI Regional Station, Pusa (Bihar), India, and were used for the calculation of water use. The other parameters were calculated as given below :

1. Irrigation water use (mm) = sum of mean depth of each irrigation (mm)
2. Total water use (mm) = (irrigation water use + rainfall) – drainage water
3. Water productivity (kg $ha.mm^{-1}$) = grain yield (kg ha^{-1})/water use (mm)
4. Water saving in SWI (%) = (water use in SWI as per treatment/water use in conventional line sown wheat) × 100

RESULTS AND DISCUSSION

Yield attributes and yield

Higher effective tillers, grains spike^{-1} and 1000-grain weight of wheat were observed in seed treated plots as compared to plots with untreated seed, but the increase was non-significant. However, SWI wheat sown at 10 cm × 10 cm spacing recorded significant higher effective tillers (345.7 and 405.8 m^{-2}) as compared to SWI at 15 cm × 15 cm or 20 cm × 20 cm spacing during both the years but it was *at par* with conventional line sowing (Table 1). Styger (2009) obtained more number of tillers m^{-2}, panicle m^{-2} and tillers hill^{-1} in rice planted under SRI method as compare to farmers practices. Similarly in wheat, though the number of tillers per seed is found 4 to 5 times more in SWI method but increase in total number of tillers m^{-2} were marginal as compare to conventional line sowing. Significantly higher test weight was recorded in SWI methods irrespective of spacing as compared to conventional line sowing (Table 1). This may be due to the wider spacing and proper aeration under SWI method. The results revealed that there was no significant difference in yield due to treatment of seed before sowing during both the years. SWI method of wheat sowing at 10 cm × 10 cm spacing recorded signi-ficantly higher grain yield (6.6 and 5.1 t ha^{-1}) during 2011-12 and 2012-13, respectively over other treatments (table 1). Straw yield obtained in the given treatment was also significantly higher (8.2 t ha^{-1}) during 2011-12 but *at par* during 2012-13. It may be due to the alteration in the vegetative character of variety. During 2012-13 conventionally tilled wheat recorded signi-ficantly highest straw yield of 8.1 t ha^{-1} which remain at par with SWI sowing at 10 cm x 10 cm spacing (Table 1). Similar results has also been reported by Adhikari, 2013 from his experiment at farmers fields at Sindhuli, Nepal where wheat variety "Bhirkuti" has yielded 2.6, 2.4 and 2.3 kg plot^{-1} of 4 m^2 size *i.e.*, 6.5, 6.0 and 5.75 t ha^{-1} in SWI, line sowing and broadcast methods, respectively. Chopra and Sen (2013) has also reported grain yield of wheat to the tune of 4.4, 3.5, and 2.0 t/ha with SWI at 25 cm × 25cm plant spacing, line sowing at 25 cm and wheat sown under broadcast method respectively. But on the contrary, Abraham *et al.* (2014) reported an increase of 18 to 67% grain and 9 to 27 % straw yield of wheat at farmers field in SWI as compared to broadcast method. Later on, in 2011-12, People's Science Institute (PSI), working in Uttarakhand and Himanchal Pradesh, found that average increase in grain yield from irrigated SWI reached to 80 to 100 % over usual farmers practice, whereas, The Aga Khan Rural Support Programme, working in farmers fields at Bihar has reported grain yield of wheat to the tune of 3.48 t ha^{-1} in SWI as compare to usual practice (2.63 t ha^{-1}) (Abraham *et al.*, 2014). Perusal of results of present investigation in light of reports available from various agencies it may be inferred

Table 1. Yield and yield attributes of wheat as influenced by different methods of wheat cultivation

Treatment	Effective tillers m^{-2}		Grains spike^{-1}		1000-grain weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Seed treatment										
Treated	318.8	359.9	50.4	47.0	46.2	36.3	6.4	4.9	7.9	7.9
Untreated	307.7	362.4	47.5	46.5	44.0	36.0	6.2	4.8	7.7	8.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sowing method/spacing										
Conventional sowing (22.5 cm line)	325.8	383.0	45.1	44.4	43.4	34.8	6.1	4.7	7.6	8.1
SWI at 10 cm × 10 cm	345.7	405.8	52.5	45.9	44.5	35.7	6.6	5.1	8.2	8.0
SWI at 15 cm × 15 cm	293.7	352.0	48.4	47.7	45.5	36.9	6.2	5.1	8.0	8.1
SWI at 20 cm × 20 cm	287.8	303.8	49.8	48.9	46.9	37.1	6.3	4.5	7.9	7.8
CD (P=0.05)	36.36	49.51	NS	NS	0.79	0.46	0.28	0.48	0.65	NS

that the SWI methods are slightly superior than conventional line sowing of wheat with improved recommended practices and far superior to usual farmers practice.

Economics

Conventional line sowing of wheat was found to be more economical than SWI method, irrespective of its spacing. Conventional line sowing fetched a net returns of ₹ 77,532 and 65,720 with a net benefit cost ratio of 2.54 and 2.13 during 2011-12 and 2012-13, respectively (Table 2). It may be due to the fact that requirement of manual labour for sowing of wheat under SWI is much higher and unavailability of manual labour at the require time is becoming a major constraint. Sowing of wheat by SWI method at 10 cm × 10 cm spacing emerges to produce more grain yield but considering the cost and benefit of production it is not economical than conventional line sowing till mechanisation is done in SWI to replace required manual power.

Water use and productivity

SWI and Conventional line sowing methods of wheat cultivation influenced the irrigation water use and irrigation water productivity (Table 3). The number of irrigations applied in two methods of wheat cultivation were 5 and 6 whereas, use of irrigation water were 300 mm and 240 mm in conventional and SWI methods of wheat sowing, respectively. The total amount of irrigation water used in conventional line sowing of wheat was 60 mm more than SWI method, it was due to higher irrigation depth (6.0 cm per irrigation) in conventional line sown crop as against 4.0 cm per irrigation in SWI. Irrigation water productivity was found to be highest in

Table 2. Economics of wheat cultivation as influenced by different methods of sowing

Treatment	Cost of cultivation (000 × ₹ ha^{-1})		Gross returns (000 × ₹ ha^{-1})		Net returns (000 × ₹ ha^{-1})		B:C ratio	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Seed treatment								
Treated	41.7	42.1	113.6	98.2	71.9	56.1	1.72	1.33
Untreated	40.9	41.3	109.8	97.1	69.0	55.9	1.69	1.35
Sowing method								
Conventional sowing (22.5 cm line)	30.5	30.8	108.1	96.6	77.5	65.7	2.54	2.13
SWI at 10 cm × 10 cm	46.5	47.4	117.4	101.4	70.9	54.1	1.53	1.14
SWI at 15 cm × 15 cm	44.4	44.8	111.9	100.9	67.5	56.0	1.52	1.25
SWI at 20 cm × 20 cm	42.3	42.7	111.8	92.0	69.6	49.3	1.65	1.15

Table 3. Effect of different sowing methods of wheat on irrigation water use and its saving

Treatment	Grain yield (t ha^{-1})		Total water saving over conventional (%)		Irrigation water saving over conventional (%)		Irrigation water productivity (kg ha. mm^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Sowing method								
Conventional sowing (22.5 cm line)	6.05	4.74	0.0	0.0	0.0	0.0	20.2	15.8
SWI at 10 cm × 10 cm	6.60	5.14	17.3	17.8	20.0	20.0	27.5	21.4
SWI at 15 cm × 15 cm	6.22	5.07	17.0	17.8	20.0	20.0	25.9	21.1
SWI at 20 cm × 20 cm	6.25	4.50	17.0	17.8	20.0	20.0	26.0	18.8
CD (P=0.05)	0.28	0.48	-	-	-	-	-	-

SWI method with 10 cm × 10 cm spacing (27.5 and 21.4 kg ha.mm^{-1}) as compared to conventional (20.2 and 15. 8 kg ha.mm^{-1}) line sowing in 2011-12 and 2012-13, respectively. Thus, there was water saving of 17.3 and 17.8 % in 2011-12 and 2012-13, respectively in SWI method of wheat sowing as compared to conventional line sowing (Table 3). Similarly, Uphoff (2012) in his booklet supplement has summarised the results from wheat sown under SWI in farmers field reported that a 30% water saving is observed in SWI as compared to farmers practice. Low to very high irrigation water saving and water productivity has been reported by workers on different crops. But, fact remains as concluded by Dass and Shiva Dhar (2014), in case of rice that irrigation may exert tremendous influence on soil environment and performance of rice grown with SRI method but site specific strategies are to be developed. Same principle may be applied to wheat grown with SWI methods, where soil and water based irrigation water use and savings needs to be further evaluated. The conclusion drawn from the above study shows that wheat sown under System of Wheat Intensification (SWI) at 10 cm × 10 cm spacing is better than conventional line sowing in terms of grain and straw yields. This method also save about 17 to 18 % of irrigation water and improve irrigation water productivity to the tune of 7 % as compared to conventional line sowing.

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Evaluation of an offset rotavator for different type of orchards

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ABSTRACT

Rotary tillage implements are now being projected as important equipment that result in production of fine-tilth soil. However, the rotavator being in line with the tractor at the back cannot be used in orchards due to the hindrance posed by narrow space between the trees. Hence, there is a need of some tillage tool in offset to the central line of tractor so that it can reach to the area under the tree with the tractor placed in between the rows. In the offset working condition (offset rotavator) the rotary tillage unit can easily reach the strip of soil under low trees and vegetation where tractors could not operate because of limited height. An offset rotavators were mostly imported to our country and evaluated to find their suitability under Indian conditions. The study was undertaken to examine the influence of λ - ratio, depth of cut at different orchards fields such as mango, guava, and sapota with dependent parameters such as draft, fuel consumption, power consumption, field efficiency, and residue incorporation by an offset rotavator. In this paper the results indicated that as the λ - ratio and depth of cut increases, the value of draft, fuel consumption, power consumption also increases.

Key words: λ - ratio, Depth of cut, Offset rotavator, Orchard

Approximately 20% of energy for production agriculture is used for field operations, with a majority of this energy applied toward tillage operations (Stout *et al.*, 1984). Allmost, all the conventional tillage implements are passive tillage implements for soil- implement interface. The power for these implements is supplied by the tractor through soil-type interface. Only about 40-56% of net engine power is available at the drawbar of a tractor when transmitting power through the soil-type interface, whereas it is about 80-85% for PTO driven active tillage tools (Taylor and Burt, 1975). Poor transmission efficiency, mainly due to high wheel slippage at the soil-tyre interface, reduces the tillage efficiency of the implements. Conventional tillage is an energy intensive method and there is a need for implements, which should ensure timeliness of field operations, besides being cost and energy effective. Transmission of power to the soil engaging tools through PTO of tractor reduces inefficiency of soil-tyre interface. The PTO driven tools transmit power directly to the soil rather than being pulled through it. These implements are more effective in soil pulverization, cutting ability and require less draft. The soils with moderate hardness can be prepared more rapidly by rotary powered implements. These implements can play an important role in multiple cropping systems where time is the main constraint for land preparation. Rotavator tools obtain their energy in more than one manner, reduce the draft requirement and have greater versatility in manipulating the soil to obtain the desired result. Thus, rotavator also reduces the time required to get an optimum seedbed by combining the primary and secondary tillage operation. A rotary tiller is a type of motorized cultivating equipment that breaks or works the soil with the aid of rotating blades (Zareiforoush *et al.*, 2010). It saves 30-35% of time and 20-25% in the cost of operation as compared to tillage by cultivator. It gives higher quality of work (25-30%) than tillage by cultivator (Shinde *et al.*, 2012). This allows the farmer to increase his farm acreage and becomes less dependent on hired farm labor, performs operations more timely and obtains higher yields, (Sharda *et al.*, 2004, Chertkiattipol *et al.*, 2008 and Sahay *et al.*, 2009). The tractor power through non-reactive means could reduce draft requirements, the tractor could be made lighter which would reduce its cost and soil compaction. It has been found that the degree of soil pulverization attained by the rotavator is comparable with the use of a mould board plough, and harrow (twice) and spiked tooth harrow, (Bukhari *et al.*, 1996). Sinha and Ram (1998) reported that the energy required per unit volume of soil for rotavator is only 39.2-47.0 MJ/m^3 as compared to 62.2-103 MJ/m^3 in MB plough desi plough cultivator respectively. The farmers are increasingly accepting rotavators for high degree of pulverization (Kepner *et al.*, 1987).

Rotary tillage implements are now being projected as important tools in production of fine tilth soil; however the rotavator being in line with the tractor at the back cannot be used in orchards due to the hindrance posed by narrow space between the lines of tree of the orchards. Hence, there is need of some tillage tool in offset model to central line of tractor so that it can reach canopy of orchards with the tractor in between rows. Offset rotavators have been found to be the most suitable for this purpose. An important feature of this rotary tillage tool is the side shift system, based on a hydraulic cylinder, activated from the tractor cabin, adjusts the offset working position quickly and without any effort. The side-shift rotary tiller is used mainly for tilling in vineyards and orchards and generally in row crops which require a working element which can be offset adjusted hydraulically through the tractor hydraulic device with an adjustable offset of about 30-50 cm.

In the offset working condition (offset rotavator) the rotary tillage unit can easily reach the strip of soil under low trees and vegetation where tractors could not operate because of limited height. The offset rotavator under study was imported and evaluated on case to case basis to find their suitability under Indian conditions and also promote domestic manufacturing of these offset rotavator.

MATERIALS AND METHODS

The field experiment was carried-out in a sandy-clay loam soil at Horticultural Research Center, Patthar chathah, G.B. Pant University of Agriculture and Technology Pantnagar, (U.S. Nagar) Uttarakhand, during the year 2011-2012.The study was undertaken to examine the influence of λ - ratio and depth of cut on different parameters of an offset rotavator. During the experiment the performance of an offset rotavator at the three different orchard fields of mango, guava and Sapota were selected. The different dependent parameters determined during the experiment were fuel consumption, draft measurement, power consumption, field capacity, residues incorporation, clod weight mean diameter were measured to assess the suitability of offset rotavator in India. The independent parameter selected in the experiment was depth of cut for λ - ratio and different orchard fields. The result obtained during the course of study were analyzed statistically by using the three factorial design, (RBD) randomized block design. The rotary tine set are built in three working sizes; five-flange set (55 cm), six-flange set (70 cm) and seven-flange set (85 cm). There are three possible machine size determined by the extension from the center of the tractor to the tillers right-hand outer extremity that is 1.6, 2.0 and 2.2 m. The rotor is powered mechanically by the spiral bevel gearbox and internal cardan shaft. The shifting movement that allows for the machine to avoid plant stocks is provided by a parallel arm system supported by ball bearing, and the necessary drive is guaranteed by the independent oil hydraulic system.

Draft is measured by two tractors and a dynamometer. when the tractor a was in neutral gear condition but implement in operating condition and again which the implement was in lifted position. The difference between two readings gives the draft requirement of implement.

Draft of implement = pull required at load condition — pull required at no load condition. Draft power requirement for the operation of implement can be calculated by the following Formula for calculation :

$$PS = 2\pi NT/4500$$

Where,

PS = Pto horse Power
T = Torque (kgf.m)
N = Revolution (rev/min)

The residue incorporation is expressed on percentage basis.

Residue incorporation (%) = (WB-WA)/WB × 100

Where,

WB = Number of weed present per unit area before the operation.
WA = Number of weed present per unit area after the operation.

RESULTS AND DISCUSSION

The results obtained during the course of study were analyzed statistically by using the three factorial designs (RBD). The statically analysis (ANOVA) is given different tables indicated that orchard field, λ-ratio and depth of cut have significant effect on the draft, fuel consumption, power consumption, mean mass diameter, field capacity, field efficiency, and residue incorporation at 5% level of significance.

Effect of λ - ratio and depth of cut on the draft requirement by an offset rotavator

Table 1 presents the draft required at different λ-ratios and depth of cut. The maximum draft in mango, guava and Sapota orchard were found to be 115.45, 117.25 and 121.12 kgf at a λ-ratio of 2.8 and depth of cut 12 cm respectively. The minimum draft in mango, guava and Sapota orchard were found to be 74.36, 49.93 and 85.45 kgf at λ-ratio of 2.1 and depth of cut 5 cm respectively. In general it was found that the λ-ratio increases draft will also increases. This was due to the increase of the λ-ratio and the value of draft which lead the increases forward.

Table 1. Effect of λ-ratio and depth of cut on draft (kgf) requirement by an offset rotavator under different orchard fields

Experi-ment No.	Orchards field	λ-ratio	Depth of cut	Average value of draft (kgf)
1	F_1	λ_1	D_1	74.36
2	F_1	λ_1	D_2	79.0
3	F_1	λ_1	D_3	95.2
4	F_1	λ_2	D_1	75.5
5	F_1	λ_2	D_2	80.14
6	F_1	λ_2	D_3	105.0
7	F_1	λ_3	D_1	95.25
8	F_1	λ_3	D_2	110.60
9	F_1	λ_3	D_3	115.45
10	F_2	λ_1	D_1	49.93
11	F_2	λ_1	D_2	81.73
12	F_2	λ_1	D_3	95.63
13	F_2	λ_2	D_1	85.33
14	F_2	λ_2	D_2	97.12
15	F_2	λ_2	D_3	115.15
16	F_2	λ_3	D_1	90.43
17	F_2	λ_3	D_2	98.13
18	F_2	λ_3	D_3	117.25
19	F_3	λ_1	D_1	85.45
20	F_3	λ_1	D_2	89.13
21	F_3	λ_1	D_3	100.30
22	F_3	λ_2	D_1	88.55
23	F_3	λ_2	D_2	90.12
24	F_3	λ_2	D_3	114.5
25	F_3	λ_3	D_1	97.10
26	F_3	λ_3	D_2	119.15
27	F_3	λ_3	D_3	121.12

Where,

F_1 = Mango orchards F_2 = Guava orchards F_3 = Sapota orchards
D_1 = 5.0 cm D_2 = 8 cm D_3 = 12 cm
λ_1 = 1.3 λ_2 = 2.1 λ_3 = 2.8

Effect of λ - ratio and depth of cut on the fuel consumption by an offset rotavator

The fuel consumption (l/h) during the experiment for different orchards field at different λ-ratio and depth of cut are presented in the Table 2. The maximum fuel consump-tion for mango, guava and Sapota orchards were found to be 4.27 l/h at a λ-ratio of 2.8 and depth of cut 12 cm, 4.55 l/h. at λ-ratio of 2.1 and depth of cut 12 cm, 5.46 l/h. at λ-ratio of 1.3 and depth of cut 12 cm respectively. The minimum fuel consumption for mango, guava and sapota

Table 2. Effect of λ-ratio, depth of cut, on fuel consumption for offset rotavator under different orchard fields.

Experiment No.	Orchards field	λ-ratio	Depth of cut	Average value of fuel consumption
1	F_1	λ_1	D_1	3.23
2	F_1	λ_1	D_2	3.42
3	F_1	λ_1	D_3	4.08
4	F_1	λ_2	D_1	3.28
5	F_1	λ_2	D_2	3.47
6	F_1	λ_2	D_3	4.19
7	F_1	λ_3	D_1	4.01
8	F_1	λ_3	D_2	3.90
9	F_1	λ_3	D_3	4.27
10	F_2	λ_1	D_1	3.26
11	F_2	λ_1	D_2	3.97
12	F_2	λ_1	D_3	4.17
13	F_2	λ_2	D_1	3.84
14	F_2	λ_2	D_2	4.35
15	F_2	λ_2	D_3	4.35
16	F_2	λ_3	D_1	3.95
17	F_2	λ_3	D_2	4.5
18	F_2	λ_3	D_3	4.55
19	F_3	λ_1	D_1	3.87
20	F_3	λ_1	D_2	4.48
21	F_3	λ_1	D_3	4.15
22	F_3	λ_2	D_1	4.94
23	F_3	λ_2	D_2	4.98
24	F_3	λ_2	D_3	5.26
25	F_3	λ_3	D_1	5.15
26	F_3	λ_3	D_2	5.18
27	F_3	λ_3	D_3	5.46

Where,
F_1 = Mango orchards F_2 = Guava orchards F_3 = Sapota orchards
D_1 = 5.0 cm D_2 = 8 cm D_3 = 12 cm
λ_1 = 1.3 λ_2 = 2.1 λ_3 = 2.8

Table 3. Effect of λ-ratio and depth of cut, on power consumption kW under different orchards fields.

Experiment No.	Orchards field	λ-ratio	Depth of cut	Average value of power consumption, (kW)
1	F_1	λ_1	D_1	2.65
2	F_1	λ_1	D_2	2.74
3	F_1	λ_1	D_3	3.02
4	F_1	λ_2	D_1	3.75
5	F_1	λ_2	D_2	3.84
6	F_1	λ_2	D_3	3.98
7	F_1	λ_3	D_1	5.46
8	F_1	λ_3	D_2	5.73
9	F_1	λ_3	D_3	6.0
10	F_2	λ_1	D_1	2.68
11	F_2	λ_1	D_2	3.59
12	F_2	λ_1	D_3	2.52
13	F_2	λ_2	D_1	4.34
14	F_2	λ_2	D_2	4.42
15	F_2	λ_2	D_3	4.62
16	F_2	λ_3	D_1	5.70
17	F_2	λ_3	D_2	5.92
18	F_2	λ_3	D_3	6.22
19	F_3	λ_1	D_1	3.99
20	F_3	λ_1	D_2	3.40
21	F_3	λ_1	D_3	3.74
22	F_3	λ_2	D_1	4.46
23	F_3	λ_2	D_2	4.76
24	F_3	λ_2	D_3	4.97
25	F_3	λ_3	D_1	6.10
26	F_3	λ_3	D_2	6.34
27	F_3	λ_3	D_3	6.66

Where,
F_1 = Mango orchards F_2 = Guava orchards F_3 = Sapota orchards
D_1 = 5.0 cm D_2 = 8 cm D_3 = 12 cm
λ_1 = 1.3 λ_2 = 2.1 λ_3 = 2.8

orchards were found to be 3.23 l/h at λ-ratio 1.3 and depth 5 cm, 3.86 l/h at λ-ratio 2.1 and depth 5 cm and 3.87 l/h at λ - ratio 1.3 and depth 5 cm respectively.

Effect of λ - ratio and depth of cut on the power consumption (kW) by an offset rotavator

The offset rotavator required the power during the experiment for different orchards field at different λ-ratio and depth of cut are presented in Table 3. The maximum power consumption for mango, guava and Sapota orchards were found to be 6, 6.22 and 6.66 kW at λ-ratio of 2.8 and depth of cut 5 cm respectively. For the same field condition the minimum power consumption for mango, guava and Sapota orchards were found to be 2.65, 2.68 and 3.19 kW at λ-ratio 1.3 and depth 5 cm respectively. In general as the λ-ratio increases the power consumption by offset rotavator also increases.

Table 4. Effect of λ-ratio and depth of cut on residue incorporation (%) under different orchards fields.

Experi-ment No.	Orchards field	λ-ratio	Depth of cut	Average value of residue incorporation, %
1	F_1	λ_1	D_1	90.00
2	F_1	λ_1	D_2	89.00
3	F_1	λ_1	D_3	92.35
4	F_1	λ_2	D_1	93.70
5	F_1	λ_2	D_2	94.55
6	F_1	λ_2	D_3	93.70
7	F_1	λ_3	D_1	93.50
8	F_1	λ_3	D_2	95.53
9	F_1	λ_3	D_3	96.68
10	F_2	λ_1	D_1	81.30
11	F_2	λ_1	D_2	83.35
12	F_2	λ_1	D_3	84.26
13	F_2	λ_2	D_1	82.66
14	F_2	λ_2	D_2	83.30
15	F_2	λ_2	D_3	85.40
16	F_2	λ_3	D_1	90.03
17	F_2	λ_3	D_2	94.13
18	F_2	λ_3	D_3	95.30
19	F_3	λ_1	D_1	87.33
20	F_3	λ_1	D_2	83.86
21	F_3	λ_1	D_3	75.50
22	F_3	λ_2	D_1	88.00
23	F_3	λ_2	D_2	90.60
24	F_3	λ_2	D_3	84.96
25	F_3	λ_3	D_1	91.53
26	F_3	λ_3	D_2	92.50
27	F_3	λ_3	D_3	76.46

Where,

F_1 = Mango orchards
F_2 = Guava orchards
F_3 = Sapota orchards
D_1 = 5.0 cm
D_2 = 8 cm
D_3 = 12 cm
λ_1 = 1.3
λ_2 = 2.1
λ_3 = 2.8

Effect of different orchards field on residue incorporation (%) by an offset rotavator

The Residue incorporation, during the experiment for different orchards field at different λ-ratio and depth of cut is presented in the Table 4. The maximum residue incorporation for mango, guava and Sapota orchards were found to be 98.3(%) at a λ-ratio of 2.1 and depth of cut 8 cm, 94.13 % at a λ-ratio of 2.8 and depth of cut 8 cm and 91.53 % at λ-ratio of 2.8 and depth of cut 5 cm respectively. For the same condition the minimum residue incorporation for mango, guava and Sapota orchards were found to be, 89.00 % at λ-ratio 1.3 and depth 8 cm, 81.30% at λ-ratio 2.1 and depth 5 cm, 83.66% at a λ-ratio 2.4 and depth 8 cm respectively.

CONCLUSION

- Experimental results revealed that with the increase in the forward speed draft increases. The increase in depth of cut was also found to cause in increasing the draft.
- It was observed that as as the λ-ratio increases the fuel consumption, power consumption and residue incorporation (%) also increase.
- Offset rotavators have been found to be the most suitable for tilling in vineyards and orchards and generally in row crops. It can easily reach the strip of soil under low trees and vegetation where tractors could not operate because of limited height . The offset rotavator need to be evaluated on case to case basis to find their suitability under Indian conditions.

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Effects of seed cutting and treatment methods of potato on yield, quality and profitability of French fry variety *Kufri Frysona*

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ABSTRACT

Field studies were conducted at CPRI Campus, Modipuram (India) with French fry variety Kufri Frysona. The eight treatments consisted of whole vs cut seed piece, untreated or treated with fungicide and foliar spray of GA @10 and 20 ppm at 60 days after planting, were tested with the objective to increase French fry grade (FFG) tuber yield and net returns by decreasing the cost of seed tubers. Among treatments cut seed piece (30 g) treated with mancozeb (0.2%)+carbendazim (0.2%)+dusting of plaster of Paris (0.5%) was found best for FFG tuber number, FFG and net tuber yield besides maintaining good processing quality traits (fry colour, glucose content) at harvest and after long term storage upto 150 days. The same treatment also recorded maximum net returns and benefit cost ratio due to higher tuber yield and reduced seed cost by about 50%.

Key words: *Kufri Frysona*, fry quality, seed piece, storability, tuber yield,

The potato varieties released till 1998 in India were all meant for table purpose and none had the desirable attributes for making chips or French fries. For making good quality French fries the solids content should be high (> 20%) and glucose content should be as low as possible (preferably < 50 mg/100 g fresh weight). Thus, the variety *Kufri Frysona* was released in 2009, integrating higher French fry grade and good quality attributes (Singh *et al.*, 2010). However, the potato yield and quality is known to be affected by growing environments and agronomic practices besides genotype. Among the cultural practices the seed rate, seed size, number of eyes/tuber are the factors which affect the plant growth and finally the tuber yield and quality (Rykbost and Locke, 1999; Nolte *et al.*, 2003). Size of the seed potato affects the number of stems/hill, as number of eyes per tuber is related to the surface area of the tuber. Therefore, large tubers lead to more number of stems per hill and ultimately higher tuber number/plant and reduced average tuber weight besides higher seed rate. Since seed potato is the precious material, therefore, its use in large quantity will lead to higher cost of cultivation on one hand and its dumping into the soil will lead to wastage of food material on other hand. It is documented that seed accounts for about 40% of the total cost of cultivation, hence its judicious use is very important for profitable potato farming. Seed rate comes out to be low by planting small tubers or by using cut seed pieces, besides increased average tuber weight. Cutting of the tuber should be done before the start of sprouting to avoid damage to the sprouts. Tubers should be cut longitudinally with utmost care that each piece has at least 2 to 3 eyes and should be treated with fungicides to avoid fungal infection (Kumar *et al.*, 2013). It is also known as well as it's my personal observation that some farmers in districts of Firozabad and Agra in Uttar Pradesh use very low concentration of gibberellic acid (GA) as foliar spray during peak tuber bulking phase on potato variety *Kufri Bahar* to increase its length for fetching higher market price. Therefore, the aim of this study was to increase the French fry grade proportion in the total produce either by manipulation of seed size through manual cutting or by foliar spray of GA for cell enlargement to make the production of *Kufri Frysona* more remunerative to the farmers and processors.

MATERIALS AND METHODS

The field experiment was conducted in sandy loam soil (Typic Ustochrept) during 2008-2010 at Central Potato Research Institute Campus, Modipuram, India (29o 4' N; 77° 46' E; 237 m amsl) in randomized block design with four replications. The treatments consisted of eight combinations of seed cutting, GA application, fungicide application [T_1: whole seed tuber of (60 g); T_2: whole seed tuber (60 g)+10 ppm GA, foliar spray at 60 d; T_3: whole seed tuber (60 g)+20 ppm GA, foliar spray at 60 d; T_4: whole seed tuber (40 g); T_5: longitudinally cut seed piece (30 g) treated with 0.2% mancozeb; T_6: longitudinally cut seed piece (30 g) treated with 0.2% mancozeb+0.2% carbendazim+ 0.5% dusting with plaster of Paris (POP); T_7: cut seed piece (2-3 eyes) of 30 g treated with 0.2% mancozeb; T_8: cut seed piece (2-3 eyes) of 30 g treated with 0.2% mancozeb+0.2% carbendazim + 0.5% dusting with plaster of Paris]. Chemical analysis of the soil (0-15 cm) showed neutral pH (7.2), low organic carbon (0.35%) and low alkaline $KMnO_4$-N (167.4 kg/ha), high 0.5 *M* $NaHCO_3$ extractable P (58.6 kg/ha) and medium 1N ammonium acetate extractable K (148.8 kg/ha). Half N (135 kg/ha), full P (52.4 kg/ha) and full K (99.6 kg/ha) were applied at the time of planting. The remaining half N (135 kg/ha) was applied at the time of hilling (25 days after planting). Nitrogen was applied through calcium ammonium nitrate at the time of planting and through urea at hilling. Phosphorus and potash were applied through diammonium phosphate and muriate of potash, respectively. The experimental crop was planted on 22 and 24th October during 2008 and 2009, respectively. Well-sprouted seed tubers/cut seed piece were planted at a spacing of 67.5 × 25 cm in plots of 4.05 × 4.0 m. The experimental crop was raised under assured irrigation using the furrow method. Observations on growth parameters, such as plant height, stem number and compound leaf number were recorded from five randomly selected potato plants from each plot at 60 days after planting (DAP). Dehaulming was done manually at 120 DAP and harvesting was done two weeks later after skin setting. At harvest, French fry grade (> 75 mm long), chip grade (45-75 mm) and small grade (< 45 mm) tuber number and yield were recorded at harvest from the whole produce of the plot. To calculate net yield, seed tuber weight was deducted from the total tuber yield. To estimate tuber dry matter content five French fry grade tubers from each plot were chopped in fine pieces and 50 g sample was oven dried at 80 °C till constant weight was achieved (Kumar *et al.*, 2012). Tuber specific gravity was measured by the Hydrometer method by taking 3.632 kg of French fry grade potato tubers from each plot (Gould, 1999).

Five fry size tubers were selected randomly from each plot and used for determining French fry colour score. Potato fries were prepared at laboratory scale which involved peeling of tubers in abrasive peeler, cutting into 1×1cm thick French fries using manual French fry cutter, washing and drying on paper towel. Dried fries were then fried in refined sunflower oil in a thermostatically controlled deep fat fryer at 180 °C till 5 min. Fries were evaluated for fry colour on a scale of 1-10, subjectively with the help of colour cards (Ezekiel *et al.*, 2003), where scale 1 represents white fries, free from any browning and of highly acceptable colour while 10 is brown and unacceptable colour. The fries with colour range of 1 to 3 were considered acceptable. The glucose content in potato tubers was quantified using YSI Biochemistry analyzer as described by Sowokinos (1978). Data collected from the experiments were statistically analyzed using statistical software CROPSTAT 7.2 (IRRI, 2009).

To calculate net returns price of the French fry and chip grade potato tubers were taken as Rs. 5000 t^{-1} (price paid by the processors to their contract growers during those years) and the price for small grade potato tubers were taken as Rs. 3000 t^{-1} (the prevailing market price for that quality of potato tubers). Cost of cultivation includes the costs of all inputs, such as seed potatoes (₹ 10000 t^{-1}), cutting and seed treatment, fertilizer, pesticides, labour and capital. Sample of thirty French fry grade tubers from each plot was stored at 10-12°C with two isopropyl-chlorocarbamate (CIPC, a sprout suppressant) foggings for six months to investigate the effect of cut seed on fry colour and glucose content during long term storage.

RESULTS AND DISCUSSION

Plant growth traits and graded tuber number

The plant emergence and plant height was not affected significantly by the different treatments (Table 1). Stem number plant^{-1} was significantly higher in treatments involving whole tuber of 60 g with and without GA treatments and also in T_8 treatment. Higher stems plant^{-1} in big size seed tuber was due to more number of eyes as number of eyes per tuber is related to the surface area of the tuber (Kumar *et al.*, 2013). Leaf number plant^{-1} was maximum in T_2 treatment followed by T_3 but statistically similar with treatments T_1 and T_8. Numerically highest French fry grade tuber numbers ha^{-1} was observed in treatment T_8, however, chip grade and total tuber number ha^{-1} were recorded maximum with T_1 treatment (where untreated whole seed tuber was used) which was statistically at par with T_8 treatment.

French fry grade and net tuber yield

The highest French fry grade tuber yield was obtained in treatment T_8 (19.4 t ha^{-1}) followed by treatment T_6 (17.8 t ha^{-1}), in both the treatments cut seed piece was treated with mancozeb + carbendazim + POP, which indicated superiority over mancozeb alone and over foliar spray of GA (Table 2). Similarly the total yields and net yields (after deducting the seed tubers used), was also recorded maximum in treatment T_8 among all the treatments. However, it was not significantly different from some of the other treatments in statistical terms. The finding of this study carries great significance because in best treatment the use of seed rate was 50% lesser than

Table 1. Effect of seed cutting and GA application on growth traits and tuber number of cv *Kufri Frysona* (2 year pooled data)

Treatments	Emergence (%)	Plant height (cm)	Stem number plant^{-1}	Leaf plant^{-1}	Tuber number (thousand ha^{-1})		
					French fry grade (>75 mm)	Chip grade (45-75 mm)	Total
T_1 = Whole tuber (60 g)	87.1	66.6	3.73	34.6	119.8	235.7	604.6
T_2 = Whole tuber (60 g) + 10 ppm GA[a]	85.9	66.2	4.28	40.7	98.8	188.2	551.7
T_3 = Whole tuber (60 g) + 20 ppm GA[a]	87.2	66.1	4.15	38.3	106.5	218.0	603.4
T_4 = Whole tuber small (40 g)	89.8	60.1	2.49	22.6	104.0	170.7	459.5
T_5 = Treated LC seed piece (30 g)[b]	82.4	62.9	3.06	27.5	102.6	190.0	503.7
T_6 = Treated LC seed piece (30 g)[c]	76.3	61.6	3.33	28.9	92.4	170.7	450.6
T_7 = Treated cut seed piece (30 g) with 2-3 eyes[b]	81.7	62.7	3.16	30.2	104.9	193.5	538.7
T_8 = Treated cut seed piece (30 g) with 2-3 eyes[c]	89.1	67.4	3.42	32.7	127.3	200.6	567.9
CD (P=0.05)	NS	NS	0.93	8.62	NS	38.2	62.1

LC = Longitudinal cut; [a] = Foliar spray at 60 days after planting; [b] = Seed piece treated with mancozeb (0.2%); [c] = Seed piece treated with mancozeb (0.2%) + carbendazim (0.2%) + dusting of plaster of Paris (0.5%)

Table 2. Effect of seed cutting and GA application on graded tuber yield of cv *Kufri Frysona* (2 year pooled data)

Treatments*	Seed tuber used	Tuber yield (t ha^{-1}) French fry grade (>75 mm)	Chip grade (45-75 mm)	Total yield	Net yield	French fry grade (%)	Av. French fry tuber weight (g)
T_1	3.56	17.6	16.4	40.9	37.3	42.9	146.9
T_2	3.56	16.5	12.4	36.0	32.4	45.2	167.0
T_3	3.56	17.2	15.9	40.2	36.6	43.3	161.5
T_4	2.34	16.8	12.2	35.1	32.8	48.0	161.5
T_5	1.78	16.2	14.4	36.8	35.0	44.0	157.9
T_6	1.78	17.8	11.7	35.2	33.4	49.9	192.6
T_7	1.78	16.2	14.3	38.0	36.2	42.5	154.4
T_8	1.78	19.4	15.6	42.3	40.5	45.8	152.4
CD (P=0.05)	-	2.0	1.6	4.4	3.6	5.2	32.3

*treatment details are given in Table 1

control treatment or farmers practice (T_1). Rykbost and Locke (1999) also reported that seed piece size is an important management tool for manipulation of tuber size to achieve specific market requirements.

Economics

To find out the viability and adaptability of any agronomic intervention, the analysis of economic variables is must to ensure either reduced cost of cultivation or higher net profits. In our study the maximum net returns (₹ 1,21,740/ha) and B:C ratio (2.62) was recorded with treatment T_8 which was statistically higher than rest of the treatments tested for variety *Kufri Frysona* (Table 3). This can be attributed to numerically higher yields (French fry grade and total) and 50% lower seed cost compared to whole seed tuber (T_1) or control treatment. Rykbost and Locke (1999) also reported that profits was maximum when 50 g seed piece was used in case of variety Russet *Norkotah* compared to 64 g or 78 g seed piece of potato.

Fry quality parameters at harvest

Specific gravity is an indirect indicator of tuber solids content and starch content. The higher specific gravity is desirable for French fry

Table 3. Effect of seed cutting and GA application on economics and processing quality traits of cv *Kufri Frysona* at harvest (2 year pooled data)

Treatments*	Net returns (₹ ha^{-1})	B:C ratio	Specific gravity	Tuber dry matter Content (%)	French fry colour	Glucose Content (mg 100^{-1} g FW)
T_1	100,100	2.10	1.091	24.3	2.17	7.63
T_2	74,200	1.81	1.092	24.9	2.08	14.30
T_3	94,200	2.02	1.090	24.0	2.50	23.80
T_4	84,900	2.08	1.092	24.8	2.22	18.50
T_5	97,440	2.31	1.091	24.2	2.38	17.05
T_6	89,440	2.19	1.091	24.4	2.38	26.42
T_7	100,840	2.36	1.091	23.6	2.27	7.85
T_8	121,740	2.62	1.090	25.2	1.87	21.42
CD (P=0.05)	20,200	0.35	NS	NS	NS	NS

*treatment details are given in Table 1

making to get higher finish product recovery and lesser oil consumption during frying, favours the economics of production, superior taste and longer shelf life of the finished product (Pavlista and Ojala, 1997). Tuber specific gravity was not affected by different treatments of seed cutting and foliar spray of GA (Table 3). Besides the taste and texture of fries, the colour of fries should be free from any kind of browning which leads to deterioration of visual appeal and is associated with bitter taste. There was no significant effect of different treatments on tuber dry matter content, French fry colour and glucose content, however numerically highest tuber dry matter content was recorded in T_8 treatment (Table 3).

Fry quality parameters during storage at 10-12°C and under room temperature

Since potato is a seasonal crop and a perishable commodity, therefore to run the French fry industry on round the year, long term storage is imperative. For this purpose storage at elevated temperatures (10-12°C) with sprout suppressant treatment is done extensively to avoid the low temperature sweetening. Therefore, any agronomic manipulation done to increase the French fry grade, should not affect the quality at harvest as well as during storage. In this study as far as glucose content is concerned, the treatment of longitudinal cut with mancozeb, bavistin and POP (T_6) had consistently maintained low glucose levels till the end of study after six months (Table 4). However, this was not reflected in the fry colour, which was on higher side especially after 150 and 180 days. It is postulated that besides glucose, levels of sucrose, fructose and even nitrogenous compounds can affect colour of fried products (Kumar *et al.*, 2004). Since only glucose was analyzed in this study, the exact reason for higher fry colour cannot be speculated. The other treatments which had yielded acceptable fry colour upto 150 days include, normal seed with 10 ppm GA (T_2) , normal seed with 20 ppm GA (T_3), cut seed piece (2-3 eye) treated with mancozeb (T_7), cut seed piece (2-3 eye) treated with mancozeb + bavistin + PoP (T_8). Since our ultimate interest is in getting better overall product quality, these treatments can be adjudged as satisfactory for long term storage.

Table 4. Effect of seed cutting and GA application on processing quality of cv *Kufri Frysona* during storage at 10-12°C temperature with sprout suppressant CIPC

Treatments*	Days after storage at 10-12 °C with CIPC											
	30		60		90		120		150		180	
	Fry colour	Glucose **	Fry colour	Glucose **	Fry colour	Glucose **	Fry colour	Glucose **	Fry colour	Glucose **	Fry colour	Glucose **
T_1	2.65	0.50	2.25	9.51	2.95	47.25	3.05	2.26	3.40	43.08	6.00	61.50
T_2	4.50	2.01	1.25	6.50	3.20	6.64	3.10	3.31	2.86	15.41	3.66	56.91
T_3	1.20	1.29	2.63	3.31	1.90	7.34	3.60	4.11	3.06	10.65	3.93	37.91
T_4	3.00	1.41	2.38	15.1	1.70	8.28	3.60	10.76	5.00	60.70	4.73	59.20
T_5	3.80	4.48	2.63	8.92	2.30	7.19	4.25	6.23	3.30	73.16	3.68	67.87
T_6	2.60	0.43	2.75	5.60	2.20	6.28	3.10	6.04	3.80	19.62	5.73	18.58
T_7	1.95	0.88	2.25	28.38	2.25	16.5	2.15	5.33	2.93	14.87	3.46	31.37
T_8	1.10	0.79	3.08	5.32	2.05	4.08	4.60	5.26	2.46	11.37	5.13	69.50
CD (P=0.05)	1.21	NS	0.54	6.92	0.36	1.91	0.33	4.44	0.71	1.62	0.91	3.03

*treatment details are given in Table 1; ** = glucose (mg 100^{-1} g fresh tuber weight)

The French fry grade tubers were also stored in small quantity (5kg) at room temperature to study the physiological losses in terms of sprouting and total weight loss. There was no significant effect of different treatments on these two parameters upto 90 days of storage (data not shown). However minimum weight loss after 90 days of storage in numerical terms was obtained in treatment T_8 (13.4%) and maximum in T_1 and T_3 treatments (20.4%). Sandhu *et al.*, (2014) also reported the similar pattern of physiological weight loss for Indian potato processing variety *Kufri Chipsona-1* under Amritsar conditions.

CONCLUSIONS

The treatment T_8 (cut seed pieces of 30 g treated with 0.2% mancozeb, 0.2% carbendazim and 0.5% dusting of plaster of Paris was found best over other treatments with respect to French fry grade tuber numbers, yield, quality at harvest and after storage, net retunes, and benefit:cost ratio for variety *Kufri Frysona*. This treatment also saves the seed requirement by 50%, which is most critical and expensive input for the potato farming.

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Effect of foliar application of potash and micronutrients on growth and yield attributes of groundnut

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Abstract

A field experiment was conducted during summer season of 2012 on medium black soil to study the effect of foliar application of potash and micronutrients on growth and yield attributes of groundnut. The experiment consisted of six treatments (control, K @ 0.5%, Fe @ 0.5%, Zn @ 0.5%, B @ 0.2% and K @ 0.5% + Fe @ 0.5% + Zn @ 0.5% + B @ 0.2% at 40 DAS as foliar spray) thereby making six treatments tested in randomized block design with four replications. Results indicated that the application K @ 0.5% + Fe @ 0.5% + Zn @ 0.5% + B @ 0.2% foliar spray at 40 DAS results is significantly higher the plant height, number of branches per plant, dry matter at 45 and 75 DAS, number of nodules per plant, pod weight, 100 kernel weight, shelling per cent, pod and haulm yield. However, day to 50% flowering, CGR, RGR and test weight did not significantly influenced by various foliar applications.

Key words: Foliar spray, groundnut, nutrients, yield

Groundnut (*Arachis hypogaea* L.) has a distinct position among the oilseeds as it can be consumed and utilized in diverse ways. It is a rich source of edible oil (44 - 55%), high quality protein (22 - 36%) and carbohydrates (6 - 24%) and hence, it is valued both for edible oil and confectionery purposes. Groundnut kernels are consumed as raw, boiled, roasted or fried products and also used in a variety of culinary preparations like peanut candies, butter, peanut milk and chocolates (Desai *et al.*, 1999). Foliar feeding is often effective when roots are unable to absorb sufficient nutrients from the soil. Such a condition could arise from an infertile soil, a high degree of soil fixation, losses from leaching, cold soil temperatures, a lack of soil moisture or a restricted, injured, or diseased root system. To counteract the cyclic droughts, foliar fertilization with potassium in addition to soil potassium application for groundnut in Gujarat is considered beneficial (Golakiya and Patel, 1988). Groundnut is relatively sensitive to the deficiency of iron (Fe), zinc (Zn) and boron (B). Iron shortage in calcareous soils is one of the greatest challenges which farmers encounter while growing plants. Among the micronutrients, zinc plays vital role in plant growth and development. Zinc also catalyses the biosynthesis of indole acetic acid, acting as metal activator of the enzyme, there by ultimately increasing crop yield. Among various groups of crops, oilseeds appear to have the highest boron requirement followed by pulses and then tubers. Boron is very useful in the production of legume seed, proper seed setting, seed quality and helps in the absorption of nitrogen to a certain extent. The flowering period was extended in boron deficient plants (Harris and Brolman, 1966).

MATERIALS AND METHODS

A field experiment was conducted during summer season of 2012 at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh in a randomized block design with four replications. The soil was medium black in texture, alkaline in reaction (pH 7.8), medium in organic carbon (0.57 %), low to available nitrogen (237.0 kg/ha), high in available phosphorus (32.5 kg P_2O_5/ha) and medium in potassium (269.0 kg K_2O/ha) content. The experiment consisted of six treatments *viz.* Control (T_1), K @ 0.5% (T_2), Fe @ 0.5% (T_3), Zn @ 0.5% (T_4), B @ 0.2% (T_5) and K @ 0.5% + Fe @ 0.5% + Zn @ 0.5% + B @ 0.2% (T_6) at 40 DAS as foliar spray, thereby making six treatments tested in randomized block design with four replications. Fertilizers were applied as per treatment through DAP and urea at the time of sowing as basal dose. The groundnut *cv.* 'TG-37A' was sown on 16 February, 2012 using seed rate of 120 kg ha^{-1} with a row spacing of 30 cm. The crop was harvested on 11 June, 2012. Eight irrigations were applied during growing season. Intercultural operations *viz.*, thinning, hoeing and weeding were followed after 20 days of sowing to maintain recommended spacing and weed control. Fully mature and develop pods from randomly selected five plants from each plot were plucked and number of seeds were counted. The average number of pods and seeds per plants was worked out. After threshing and winnowing the weight of seeds for each net plot area was recorded in kg per plot and then converted to kg ha^{-1}.

RESULTS AND DISCUSSION

Growth parameters

Application of foliar spray @ K 0.5%, Fe 0.5%, Zn @ 0.5% and B @ 0.2% at 40 DAS (T_6) the significantly higher the plant height, number of branches per plant, dry matter at 45 and 75 DAS and number of nodules per plant and remained at par with the T_3 (Fe @ 0.5% foliar spray 40 DAS), T_4 (Zn @ 0.5% foliar spray 40 DAS) and T_5 (B @ 0.2% foliar spray 40 DAS) in plant height, number of branches per plant with T_4 (Zn @ 0.5% foliar spray 40 DAS) and T_5 (B @ 0.2% foliar spray 40 DAS), dry matter at 45 DAS, T_4 (Zn @ 0.5% foliar spray 40 DAS) in dry matter at 75 DAS and number of nodules per plant over control (Table 1). The increase in plant height, number of branches per plant at harvest, dry matter and number of nodules per plant might be attributed to the beneficial and favourable effect of foliar application of potash, iron, zinc and boron, their

Table 1. Effect of foliar application of potash and micronutrients on growth parameters of groundnut

Treatments	Plant height (cm)	Days to 50% flowering	Branches per plant	Dry matter (g/plant) 45 DAS	Dry matter (g/plant) 75 DAS	CGR at 45 and 75 DAS (g m^{-2} day^{-1})	RGR at 45 and 75 DAS (g g^{-1} day^{-1})	Nodules/ plant
T_1 : Control (Water spray)	31.4	43.4	3.5	9.1	15.1	3.2	0.01	89.4
T_2 : K @ 0.5% foliar spray 40 DAS	32.4	42.2	3.8	10.2	18.2	3.3	0.02	92.5
T_3 : Fe @ 0.5% foliar spray 40 DAS	33.6	42.4	4.1	10.5	18.5	2.8	0.01	93.2
T_4 : Zn @ 0.5% foliar spray 40 DAS	35.8	42.5	3.9	12.1	20.6	3.3	0.01	99.6
T_5 : B @ 0.2% foliar spray 40 DAS	33.9	43.1	3.9	11.1	19.1	3.2	0.02	93.2
T_6 : K @ 0.5% + Fe @ 0.5% + Zn @ 0.5% + B @ 0.2% foliar spray 40 DAS	36.9	41.9	4.3	12.6	22.2	3.4	0.02	103.2
S.Em±	1.17	1.36	0.16	0.56	0.80	0.1	0.001	3.18
C.D. at 5%	3.54	NS	0.49	1.68	2.42	NS	NS	9.59

Table 2. Effect of foliar application of potash and micronutrients on yield attributes and yield of groundnut

Treatments	Pod weight (g plant^{-1})	100 kernel weight (g)	Shelling (%)	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
T_1 : Control (Water spray)	7.3	39.7	63.5	1596	2346	40.5
T_2 : K @ 0.5% foliar spray 40 DAS	8.0	41.9	70.5	1688	2549	39.8
T_3 : Fe @ 0.5% foliar spray 40 DAS	8.4	42.7	72.8	1701	2530	40.2
T_4 : Zn @ 0.5% foliar spray 40 DAS	8.8	43.8	70.5	1710	2657	39.2
T_5 : B @ 0.2% foliar spray 40 DAS	8.4	41.6	71.4	1711	2551	40.1
T_6 : K @ 0.5% + Fe @ 0.5% + Zn @ 0.5% + B @ 0.2% foliar spray 40 DAS	9.9	44.4	76.8	1941	2888	40.2
C.D. at 5%	1.42	2.67	5.70	213	334	NS

role in the synthesis of IAA, metabolism of auxins, biological activity, stimulating effect on photosynthetic pigments and enzyme activity which in tern encourage vegetative growth of plants. The results of this investigation are in consonance with the findings of Sarkar *et al.* (1999) in groundnut, Thalooth *et al.* (2006) in mungbean and Aboelill *et al.* (2012) in groundnut. However, days to 50% flowering, CGR at 45 and 75 DAS and RGR at 45 and 75 DAS was failed to manifest significant influence with application of different treatment of foliar spray (Table 1).

Yield attributes and yield

Combined foliar spray of K @ 0.5%, Fe @ 0.5%, Zn @ 0.5% and B @ 0.2% at 40 DAS (T_6) recorded significantly higher the pod weight, 100 kernel weight, pod yield and haulm yield and remained at par with T_4 (Zn @ 0.5% foliar spray 40 DAS) in pod weight, T_2 (K @ 0.5% foliar spray 40 DAS), T_3 (Fe @ 0.5% foliar spray 40 DAS) and T_4 (Zn @ 0.5% foliar spray 40 DAS) in 100 kernel weight, T_3 (Fe @ 0.5% foliar spray 40 DAS) and T_5 (B @ 0.2% foliar spray 40 DAS) in shelling percent and T_4 (Zn @ 0.5% foliar spray 40 DAS) and T_5 (B @ 0.2% foliar spray 40 DAS) in haulm yield over control (Table 2). This might be attributed to the supply of potash and all the three micronutrients in balanced proportion throughout crop growth period. These micronutrients enhance cell division, cell elongation process and photosynthetic activity leading to production and accumulation of more carbohydrates and auxins which favours retention of more flowers ultimately leading to more number of reproductive parts per plant and yield. The similar results were recorded by Ali and Hassan (2001) in groundnut, Cakmak *et al.* (2006) in soybean and Pareek and Poonia (2011). However, harvest index was failed to manifest significant influence with application of different treatment of foliar spray.

CONCLUSION

Based on the results of one year experimentation, it seems quite logical to conclude that maximum production from summer groundnut can be secured by combined foliar spraying of K @ 0.5%, Fe @ 0.5%, Zn @ 0.5% and B @ 0.2% at 40 DAS besides the recommended dose of nitrogen and phosphorus on clayey soil with medium fertility under south Saurashtra Agro-climatic conditions.

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Composition of weeds and yield as affected by different weed management and planting patterns in field pea and baby corn intercropping system

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ABSTRACT

A field experiment was conducted during two consecutive seasons of *rabi* 2011-13 at Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar to find out the effect of planting pattern and weed management practices on weed growth and yields of field pea and baby corn in field pea (Pant P-13) + baby corn (Surya) intercropping system. The experiment was laid out in split plot design keeping four planting patterns as main plot and four weed management practices as sub plot with three replications. Paired planting of maize (30/60 cm) + field pea (2:2) and planting of maize + field pea (1:1) had lower total weed density than sole planting of field pea or baby corn. Sole planting of field pea recorded significantly higher grain (2264 and 1434 kg ha^{-1}) and straw yields (3263 and 2540 kg ha^{-1}) during 2011-12 and 2012-2013 than yield obtained as a component crop in paired planting of maize (30/60 cm) + field pea (2:2) and planting of maize + field pea (1:1). Baby corn yield was similar in sole, paired (2:2) and 1:1 planting but significantly higher stover yield of baby corn (3576 kg ha^{-1} and 3533 kg ha^{-1},during 2011-12 and 2012-2013 respectively) was obtained from sole crop than other planting methods during both the years. The lowest total weed density (66.5 and 67.3 plants m^{-2}, during 2011-12 and 2012-2013 respectively) was recorded in hand weeding at 90 days after sowing which was followed by pre-emergence application of pendimethalin 1 kg ha^{-1}, post-emergence application of imazethapyr 50 g ha^{-1} and weedy check. Hand weeding, pre emergence application of pendimethalin 1 kg ha^{-1} and post emergence application of imazethapyr 50 g ha^{-1} (30 DAS) improved yields of field pea and baby corn than weedy check.

Key words: Baby corn, Field pea, Planting pattern, Weed management, Weeds, Yield.

Intercropping of cereals with pulses is an age old practice. Pulses can do wonder when intercropped with widely spaced crops like maize, sorghum, pearl millet, cotton and sugarcane particularly in Northern India (Punjab, Haryana, Uttar Pradesh, Rajasthan, Bihar). There are evidences that intercropping of short growing grain legumes with tall cereals give higher productivity than corresponding sole crops (Rao and Willey, 1983). Field pea *(Pisum sativum)*, one of the important pulse crop of winter season has great potential to contribute to the the pulse basket in India. Maize, the queen of cereals, is cultivated worldwide round the year. During recent past, it has been used as vegetable where unfertilized cob is used for cooking purpose, popularly known as baby corn (*Zea mays* L.) (Barod *et al.*, 2012). Introduction of baby corn during off season (winter months), because of its photo and thermo insensitiveness will promote nutritive dish of the people and also fetch additional income to farming community.

Normally baby corn is planted in wider rows and a considerable portion of the incident solar radiation remains un-intercepted due to poor canopy development because of its slow growth during winter season. Slow crop growth during winter months provide ample opportunity to the growth of weeds. Maintenance of adequate crop cover turns the competition in favour of crop. Intercropping itself has been found helpful in limiting weed population by way of cutting light to them. So field pea may be introduced between the rows of baby corn. Intercropping of legumes with maize has been found to give yield advantage owing to efficient utilization of growth resources and maintenance of soil health (Singh *et al.*, 1998). Mishra (2014) reported that maize + field pea intercropping system resulted an extra advantage of 85.6 per cent in terms of maize equivalent yield over sole maize. Weed suppression in intercropping through more efficient use of environmental resources by component crops has also been reported by Mashingaizde *et al.* (2000).

Development of feasible and economically viable intercropping system depends largely on adoption of proper planting pattern as well as weed management. Efficiency of production in intercropping system could be improved by minimizing inter-specific competition between the component crops. Planting pattern alters the space available to individual plant; hence the degree of competition for natural resources becomes variable between component crops. Appropriation of suitable planting pattern is thus, necessary to bring the competition to the minimum level. Chalka and Nepalia (2005) at Navsari, Gujarat indicated that when soybean and cowpea were intercropped with maize in 2:1 row ratio, there was marked reduction in weed density and dry weight compared to sole maize. Weeds are one of the major obstacles that severely affect the productivity and quality of the component crops. Weeds compete with the crop plants for nutrients, moisture and light and thus, reduce the yield considerably. Keeping the above points in view, the experiment was conducted to see the response of weeds, field pea and baby corn to planting pattern and weed management on field pea + baby corn intercropping system.

MATERIALS AND METHODS

The experiment was conducted during *rabi* seasons of 2011-12 and 2012-13 in Dr. Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29°N, 79.3°E and 243.84 m above mean sea level). The maximum temperature during the crop season of 2011-12 and 2012-13 ranged between 17.5-36.5°C and 12.0-40.6°C, respectively. The minimum temperature during the same period ranged between 3.7-21.5°C and 2.5-23.7°C, respectively. A total rainfall of 1.16 mm and 5.44 mm were received during the crop season of 2011-12 and 2012-13 respectively. There was frost in the second fortnight of January during 2012-2013. The soil was sandy loam in texture with high in organic carbon (0.79%), low in available nitrogen (210.6 kg N ha^{-1}) and medium in available phosphorus (16.5 kg P ha^{-1}) and potassium contents (184.7 kg K ha^{-1}) and neutral in soil reaction (pH 7.3). The experiment was laid out in split-plot design with three replications. Main plot consisted of four planting patterns *viz.* field pea sole (30 cm), baby corn sole (45 cm), planting of maize + field pea (1:1) and paired planting of maize (30/60 cm) + field pea (2:2) and sub-plot consisted of four weed management practices *viz.* weedy check, hand weeding at 30 days after sowing (DAS), pre-emergence (PE) application of pendimethalin 1 kg ha^{-1} and post-emergence (POE) application of imazethapyr 50 g ha^{-1} at 30 DAS. Maize crop was fertilized with 120, 60 and 40 kg ha^{-1} of N, P_2O_5 and K_2O through urea, single super phosphate and muriate of potash respectively. Half dose of nitrogen and full dose of P_2O_5 and K_2O were applied as basal in all the plots and remaining dose of N was applied at knee high stage of the crop as top dressing. A dose of 18 kg N, 48 kg P_2O_5 and 24 kg K_2O ha^{-1} was applied to field pea sole through NPK mixture (12:32:16) applied @150 kg ha-1as basal. No additional dose of fertilizer to pea was given to intercropping system.

Weed flora of experiment field was collected and identified. The weeds falling within the quadrate (50 cm × 50 cm) were identified and counted species wise to obtain weed population.

Field pea was harvested manually with sickle when more than 80 per cent pods in all plots turned completely brown in colour. The harvested crop after sun drying for a period of about 3-4 days was threshed by beating the plant material with sticks. After threshing, grains were separated by winnowing and grain yield was recorded. Picking of baby corn cobs were done three days after silking of the cobs with hand. The fresh weight of baby corn after removing the husk per picking for each net plot was summed up to get total weight of baby corn per plot.

The data collected for various parameters were subjected to the analysis by using STPR-1, programme developed by Department of Statistics and Mathematics, College of Basic Science and Humanities, Pantnagar. Comparison of treatment means was done using critical differences (CD) at 5 per cent level of significance.

RESULTS AND DISCUSSION

Weed species

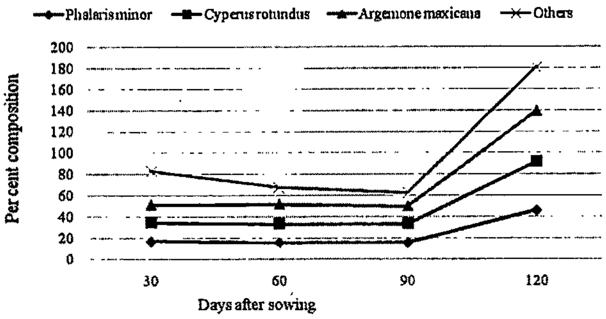

Fig. 1. Per cent composition of major weed species in weedy check treatment at different stages of crop growth.

Weed flora of experimental field were collected, identified and classified as sedges, grassy and broad leaf weeds (Table 1). Common names, families and mode of propagation of these weeds have been presented in the same table. Out of 18 weed species identified so far, three species were prominent *viz.* Phalaris minor, Cyperus rotundus and Argemone maxican under weedy check condition and per cent composition of these entire weed species remained almost constant up to 90 DAS but increased at the maturity stage of the crop (Fig. 1).

Table 1. Weed flora of experimental field during rabi seasons of 2011-12 and 2012-13

	Botanical name	Family	Common name	Mode of propagation
A.	**Annual**			
	Broad leaf weeds			
	Chenopodium album L.	Chenopodiaceae	Common lambsquarter	Seeds
	Anagallis arvensis L.	Primulaceae	Blue pimpernel	Seeds
	Melilotus alba	Leguminosae	White sweet clover	Seeds
	Melilotus indica L.	Leguminosae	Yellow sweet clover	Seeds
	Medicago denticulata L.	Leguminosae	Yellow trifoli	Seeds
	Vicia sativa L.	Leguminosae	Common vetch	Seeds
	Vicia hirsuta Linn.	Leguminosae	Hairy tare	Seeds
	Lathyrus sativa L.	Leguminosae	Yellow vetchling	Seeds
	Fumaria parviflora Lamk.	Fumariaceae	Fumitory	Seeds
	Solanum nigrum L.	Solanaceae	Black nightshade	Seeds
	Coronopus didymus L.	Brassicaceae	Swinecress	Seeds
	Polygonum plebejum	Polygonaceae	Indian knot grass	Seeds
	Linaria minor	Scrophulariaceae	Small toadflax	Seeds
B.	**Perrenial**			
	Grasses			
	Cynodon dactylon (L.) Pers.	Poaceae	Bermuda grass	Seeds, rhizomes
	Phalaris minor Retz.	Poaceae	Little seed canary grass	Seeds
	Broad leaf weeds			
	Circium arvenses (L.) Scop.	Asteraceae	Canada thistle	Seeds, roots
	Argemone mexicana L.	Papaveraceae	Mexican poppy	Seeds, roots
C.	**Sedges**			
	Cyperus rotundus	Cyperaceae	Purple nutsedge	Seeds, tubers

Weed population

Phalaris minor : Generally, both the intercropping systems recorded lower density of Phalaris minor than sole planting of either baby corn (45 cm) or field pea (30 cm) at all the stages of growth (Table 2). At 30 DAS, PE application of pendimethalin 1 kg ha^{-1} had the lowest density of Phalaris minor which was significantly lower than hand weeding (30 DAS),POE application of imazethapyr 50 g ha^{-1} (30 DAS) and weedy check during both the years. At 60, 90 and 120 DAS, hand weeding (30 DAS) recorded the lowest density of Phalaris minor and the highest density was found in weedy check during both the years.

Cyperus rotundus : At 30 DAS, planting pattern had no significant effect on density of Cyperus rotundus but at later stages of growth, both the intercropping systems had lower Cyperus rotundus density than sole planting of either baby corn (45 cm) or field pea (45 cm) (Table 3). Among the weed management practices, PE application of pendimethalin 1 kg ha-1had the lowest density of Cyperus rotundus as compared to remaining weed management practices. At later stages of growth, its density was lowest in hand weeding (30 DAS) which was followed by PE application of pendimethalin 1 kg ha^{-1}, POE application of imazethapyr 50 g ha^{-1} (30 DAS) and weedy check.

Argemone maxicana : Generally, both the intercropping systems had lower density of Argemone maxicana than sole planting of either baby corn (45 cm) or field pea (30 cm) (Table 4). Among the weed management practices, PE application of pendimethalin 1 kg ha^{-1} had the lowest density of Argemone maxicana as compared to remaining weed management practices at 30 DAS. At later stages of growth, its density was lowest in hand weeding (30 DAS) which was followed by PE application of pendimethalin 1 kg ha^{-1}, POE application of imazethapyr 50 g ha^{-1} (30 DAS) and weedy check.

Other weeds : Paired planting of maize (30/60 cm) + field pea (2:2) had the lowest density of

Table 2. Effect of planting patterns and weed management practices on density of Phalaris minor (plants/m^2) during 2011-12 and 2012-13

Treatment	Density of *Phalaris minor* (plants m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Planting pattern								
Field pea sole (30 cm)	3.38(29.1)	3.44(31.2)	3.25(27.2)	3.33(30.6)	3.10(22.6)	3.13(23.2)	2.78(17.3)	2.74(17.3)
Baby corn sole (45 cm)	3.35(28.1)	3.33(27.4)	3.57(37.5)	3.61(39.0)	3.19(24.9)	3.12(23.8)	3.12(23.0)	2.72(15.5)
Planting of maize + field pea (1:1)	3.36(28.9)	3.50(33.1)	3.18(25.0)	3.30(28.2)	3.03(20.9)	3.16(23.7)	2.84(17.6)	2.89(18.1)
Paired planting of maize (30/60 cm) + field pea (2:2)	3.39(29.5)	3.54(34.7)	3.14(24.5)	3.30(28.6)	3.00(20.1)	3.06(21.9)	2.81(16.7)	2.72(16.4)
CD at 5%	NS	0.08(3.7)	0.07(3.5)	0.19(6.1)	0.05(1.1)	NS	0.05(0.9)	0.10(2.3)
Weed management								
Weedy	3.52(33.1)	3.57(35.3)	3.82(46.1)	3.94(51.5)	3.49(32.1)	3.53(34.1)	3.44(30.3)	3.35(28.5)
Hand weeding (30 DAS)	3.43(30.2)	3.55(34.0)	3.02(19.8)	3.07(21.2)	2.94(18.6)	2.88(17.9)	2.63(13.0)	2.33(9.7)
Pendimethalin 1 kg ha^{-1} (PE)	3.02(19.6)	3.11(21.7)	3.10(22.4)	3.18(24.1)	2.89(17.7)	2.98(19.1)	2.64(13.8)	2.62(13.1)
Imazethapyr 50 g ha^{-1} (POE, 30 DAS)	3.51(32.9)	3.58(35.4)	3.20(26.0)	3.34(29.6)	3.00(20.1)	3.08(21.5)	2.85(17.5)	2.78(15.9)
CD at 5%	0.08(2.5)	0.10(3.6)	0.08(4.5)	0.10(4.5)	0.12(2.3)	0.11(3.4)	0.06(0.9)	0.10(2.3)

*Original values are in parentheses and values outside the parenthesis are log (x+1) transformed; DAS: days after sowing; PE: pre emergence; POE: post emergence; NS: non significant

Table 3. Effect of planting patterns and weed management practices on density of *Cyperus rotundus* (plants m^{-2}) during 2011-12 and 2012-13

Treatment	Density of *Cyperus rotundus* (plants m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Planting pattern								
Field pea sole (30 cm)	3.38(29.3)	3.41(30.3)	3.31(28.4)	3.25(27.0)	3.10(22.8)	3.14(23.9)	2.39(10.2)	2.33(9.7)
Baby corn sole (45 cm)	3.37(29.1)	3.29(26.7)	3.67(40.4)	3.76(45.2)	3.36(30.2)	3.47(33.1)	2.74(15.5)	2.53(12.4)
Planting of maize + field pea (1:1)	3.38(29.2)	3.43(30.6)	3.22(26.1)	3.17(24.8)	3.04(21.4)	3.08(22.5)	2.36(9.9)	2.32(9.4)
Paired planting of maize (30/60 cm) + field pea (2:2)	3.19(26.2)	3.39(29.8)	3.16(24.6)	3.12(23.4)	2.94(19.4)	2.98(20.4)	2.24(8.7)	2.19(8.3)
CD at 5%	NS	NS	0.11(2.3)	0.09(7.4)	0.16(5.2)	0.06(2.3)	0.19(3.2)	0.11(1.6)
Weed management								
Weedy	3.38(31.8)	3.51(32.9)	3.87(47.7)	3.85(47.6)	3.60(36.2)	3.66(38.9)	2.73(14.8)	2.62(13.3)
Hand weeding (30 DAS)	3.40(29.3)	3.49(32.0)	3.11(22.0)	3.10(22.1)	2.73(14.9)	2.80(16.0)	2.26(8.7)	2.17(7.9)
Pendimethalin 1 kg ha^{-1} (PE)	3.04(20.0)	2.99(19.1)	3.17(23.3)	3.16(23.3)	2.93(18.0)	2.97(19.2)	2.26(9.0)	2.20(8.1)
Imazethapyr 50 g ha^{-1} (POE, 30 DAS)	3.51(32.6)	3.53(33.6)	3.21(26.6)	3.20(27.4)	3.19(24.7)	3.23(25.9)	2.48(11.8)	2.38(10.5)
CD at 5%	0.29(5.2)	0.08(2.8)	0.05(2.3)	0.09(4.9)	0.09(3.0)	0.11(3.7)	0.08(1.1)	0.12(1.5)

*Original values are in parentheses and values outside the parenthesis are log (x+1) transformed; DAS: days after sowing; PE: pre emergence; POE: post emergence; NS: non significant

Table 4. Effect of planting patterns and weed management practices on density of *Argemone maxicana* (plants/m^2) during 2011-12 and 2012-13

Treatment	Density of *Argemone maxicana* (plants m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Planting pattern								
Field pea sole (30 cm)	3.24(26.1)	3.26(26.4)	2.83(19.4)	2.92(21.5)	2.72(16.8)	2.68(16.0)	2.36(10.2)	2.29(9.5)
Baby corn sole (45 cm)	3.29(27.3)	3.42(31.5)	3.45(35.2)	3.58(40.5)	3.01(22.2)	2.97(21.5)	2.26(9.9)	1.96(6.9)
Planting of maize + field pea (1:1)	3.25(26.4)	3.27(26.8)	2.83(19.6)	2.93(21.8)	2.64(15.8)	2.59(15.0)	2.21(8.3)	2.13(7.7)
Paired planting of maize (30/60 cm) + field pea (2:2)	3.21(25.7)	3.25(26.6)	2.77(18.6)	2.86(20.7)	2.57(14.8)	2.51(14.1)	2.08(7.3)	2.02(6.8)
CD at 5%	NS	0.10(3.3)	0.05(4.4)	0.05(3.2)	0.09(1.1)	0.09(1.3)	0.11(1.5)	0.14(1.8)
Weed management								
Weedy	3.44(31.0)	3.49(32.7)	3.81(45.4)	3.91(50.9)	3.52(33.9)	3.46(32.3)	2.53(12.1)	2.39(10.4)
Hand weeding (30 DAS)	3.45(30.8)	3.46(31.1)	2.46(11.0)	2.57(12.4)	2.26(8.8)	2.22(8.4)	1.91(6.0)	1.79(5.3)
Pendimethalin 1 kg ha^{-1} (PE)	2.67(13.6)	2.74(14.7)	2.74(15.0)	2.84(16.9)	2.47(11.0)	2.42(10.5)	2.12(7.6)	2.00(6.7)
Imazethapyr 50 g ha^{-1} (POE, 30 DAS)	3.43(30.2)	3.50(32.9)	2.85(21.3)	2.97(24.2)	2.68(15.9)	2.62(15.2)	2.34(10.0)	2.22(8.5)
CD at 5%	0.12(3.4)	0.11(3.5)	0.06(3.8)	0.10(5.3)	0.10(3.7)	0.10(2.8)	0.11(1.1)	0.08(1.0)

*Original values are in parentheses and values outside the parenthesis are log (x+1) transformed; DAS: days after sowing; PE: pre emergence; POE: post emergence; NS: non significant other weeds followed by planting of maize + field pea (1:1); both had lower density of other weeds than baby corn sole (45 cm) and field pea sole (30 cm) during both the years (Table 5). At 30 DAS, PE application of pendimethalin 1 kg ha^{-1} had the lowest density of other weeds as compared to remaining weed management practices. At later stages of growth, the lowest density of other weeds was recorded in hand weeding (30 DAS) and the highest value was found in weedy check.

Total weed density : The total weed population recorded at different stages in weedy check plot revealed that the crop was severely infested with weeds throughout the growth period. The density of weeds increased up to 60 days stage of crop growth and there after started decreasing. The lowest density was observed at 120 days stage in all the treatments (Table 6). The lowest weed density in the later stage was the result of drying of weeds because of intense competition among the weeds during subsequent growing period of crop and decaying of weeds due to termination of their life cycle as weeds usually have shorter life span than crop plants. Both the intercropping systems recorded lower total weed density than the sole cropping of field pea or baby corn during both the years. Lower total weed density observed in intercropping systems than sole planting of field pea or baby corn was due to the fact that intercropping provides an efficient utilization of environmental resources especially the light. Thus, the growth of weeds, depending on the availability of environmental resources was decreased. Weed suppression in intercropping through more efficient use of environmental resources by component crops has also been reported by Poggio (2005). Sole and intercropped field pea reduced the population and dry weight of weeds more than that of baby corn sole due to its smothering effect. Kurchania *et al.* (1995), Dubey (1998) and Sanjay *et al.* (2011) also reported similar findings. Hand weeding (30 DAS) recorded the lowest total weed density which was followed by PE application of pendimethalin 1 kg ha^{-1}, POE application of

Table 5. Effect of planting patterns and weed management practices on density of other weeds (plants m^{-2}) during 2011-12 and 2012-13

Treatment	Density of other weeds (plants m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Planting pattern								
Field pea sole (30 cm)	4.35(80.0)	4.30(78.2)	4.05(66.1)	4.04(66.8)	3.85(53.0)	3.83(53.2)	3.20(27.5)	3.05(24.8)
Baby corn sole (45 cm)	4.38(81.8)	4.44(88.0)	4.46(93.9)	4.56(105.2)	4.09(68.2)	4.24(75.7)	3.02(22.8)	2.87(19.2)
Planting of maize + field pea (1:1)	4.35(81.3)	4.33(80.7)	3.99(62.5)	3.97(61.9)	3.80(50.7)	3.75(47.9)	2.98(21.3)	2.83(18.5)
Paired planting of maize (30/60 cm) + field pea (2:2)	4.21(72.1)	4.21(72.7)	3.91(57.3)	3.93(59.2)	3.62(41.6)	3.53(38.6)	2.76(17.0)	2.64(15.0)
CD at 5%	0.08(3.4)	0.07(7.6)	0.14(10.5)	0.11(12.0)	0.07(9.8)	0.21(13.7)	0.10(5.6)	0.06(2.7)
Weed management								
Weedy	4.54(93.6)	4.57(98.0)	4.78(120.9)	4.82(126.0)	4.55(95.6)	4.51(92.7)	3.68(40.4)	3.54(35.6)
Hand weeding (30 DAS)	4.48(87.4)	4.50(90.0)	3.51(34.0)	3.48(34.0)	3.22(24.2)	3.19(25.0)	2.39(10.2)	2.14(7.6)
Pendimethalin 1 kg ha^{-1} (PE)	3.78(44.6)	3.72(41.5)	4.19(66.7)	4.20(69.2)	3.82(45.6)	3.85(47.6)	2.86(17.1)	2.77(15.5)
Imazethapyr 50 g ha^{-1} (POE, 30 DAS)	4.48(89.7)	4.49(90.2)	3.92(58.2)	4.00(64.0)	3.77(48.1)	3.80(50.2)	3.03(20.8)	2.93(18.7)
CD at 5%	0.12(9.0)	0.13(12.3)	0.12(10.4)	0.13(11.1)	0.08(7.5)	0.09(8.0)	0.12(4.8)	0.10(4.3)

*Original values are in parentheses and values outside the parenthesis are log (x+1) transformed; DAS: days after sowing; PE: pre emergence; POE: post emergence

Table 6. Effect of planting patterns and weed management practices on total weed density (plants m^{-2}) during 2011-12 and 2012-13

Treatment	Total weed density (plants m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Planting pattern								
Field pea sole (30 cm)	5.24(203.7)	5.19(190.4)	4.82(141.1)	4.86(145.9)	4.64(115.2)	4.65(116.3)	4.09(65.3)	4.02(61.2)
Baby corn sole (45 cm)	5.12(176.4)	5.23(198.1)	5.24(207.0)	5.35(229.9)	4.87(145.6)	4.95(154.1)	4.18(71.1)	3.90(53.9)
Planting of maize + field pea (1:1)	5.21(193.9)	5.17(185.1)	4.77(133.2)	4.80(136.7)	4.59(108.8)	4.59(109.1)	3.98(57.1)	3.93(53.7)
Paired planting of maize (30/60 cm)+field pea (2:2)	5.12(178.0)	5.06(165.4)	4.72(125.0)	4.76(131.9)	4.47(95.9)	4.45(94.9)	3.84(49.7)	3.78(46.4)
CD at 5%	NS	NS	0.13(29.5)	0.13(22.0)	0.15(21.6)	0.25(39.6)	0.17(8.6)	NS
Weed management								
Weedy	5.34(209.9)	5.32(206.3)	5.54(260.0)	5.60(276.1)	5.27(197.8)	5.27(198.0)	4.56(97.6)	4.45(87.7)
Hand weeding (30 DAS)	5.42(229.2)	5.42(228.4)	4.45(86.8)	4.47(89.6)	4.19(66.5)	4.20(67.3)	3.65(38.0)	3.44(30.6)
Pendimethalin 1 kg ha^{-1} (PE)	4.59(98.6)	4.63(103.2)	4.83(127.4)	4.87(133.5)	4.51(92.4)	4.55(96.4)	3.85(47.5)	3.77(43.5)
Imazethapyr 50 g ha^{-1} (POE, 30 DAS)	5.36(214.2)	5.29(201.1)	4.74(132.1)	4.82(145.1)	4.60(108.8)	4.62(112.8)	4.05(60.1)	3.96(53.5)
CD at 5%	0.07(13.6)	0.10(20.7)	0.11(19.8)	0.10(24.3)	0.11(19.5)	0.16(21.9)	0.10(8.6)	0.12(8.9)

*Original values are in parentheses and values outside the parenthesis are log (x+1) transformed; DAS: days after sowing; PE: pre emergence; POE: post emergence; NS: non significant

imazethapyr 50 gha^{-1} (30 DAS) and weedy check. Variation in the density of weeds in different weed control treatments was due to varying effect of herbicides and hand weeding on number of weeds per unit area. These results are in line with those obtained by Khan *et al.* (2002), Muhammad and Hassan (2003) and Fathi *et al.* (2003); they reported the highest weed density in weedy check plots and the lowest with chemical weed control. The interaction between planting patterns and weed management practices at 90 DAS was significant during both the years with respect to total weed density (Table 6a). Both the intercropping systems recorded lower total weed density than sole planting of field pea and baby corn under all weed management practices during both the years. The lowest total weed density was observed in hand weeding at 30 DAS which was followed by PE application of pendimethalin 1 kg ha^{-1}, POE application of imazethapyr 50 g ha^{-1} at 30 DAS and weedy check under all the planting patterns.

Yield of field pea and baby corn

Grain yield of field pea per : On an average, sole planting of field pea yielded 85.3 and 61.4 per cent more grain yield over planting of maize + field pea (1:1) and paired planting of maize (30/60 cm) + field pea (2:2) respectively (Table 7). Higher yield of field pea in the treatments where it was grown alone might be due to higher planting density, plant height and higher values of yield attributing characters. The lower grain yield of field pea grown in association with baby corn was probably the result of inter-specific competition between corn and field pea plants for below and above ground growth factors i.e. soil moisture, nutrient, space and solar radiation. The results of present investigation are in conformity with those of Carruthers et al. (2000), Banik *et al.* (2006) and Das *et al.* (2013) who reported the highest grain yield of soybean under sole planting which was statistically different from those obtained from maize + soybean at single row and maize + soybean at paired row

Table 6a. Interaction between planting pattern and weed management on total weed density at 90 DAS during 2011-12 and 2012-13

Planting pattern	Total weed density							
	2011-12				2012-13			
	Weedy	Hand weeding (30 DAS)	Pendimethalin 1 kg ha^{-1} (PE)	Imazethapyr 50g ha^{-1} (POE, 30 DAS)	Weedy	Hand weeding (30 DAS)	Pendimethalin 1 kg ha^{-1} (PE)	Imazethapyr 50g ha^{-1} (POE, 30 DAS)
Field pea sole (30 cm)	5.31 (207.2)	4.27 (73.2)	4.58 (97.6)	4.40 (82.8)	5.33 (210.7)	4.23 (69.0)	4.61 (101.1)	4.44 (84.4)
Baby corn sole (45 cm)	5.33 (211.0)	4.27 (71.4)	4.64 (105.5)	5.25 (194.3)	5.37 (218.7)	4.43 (83.9)	4.72 (114.5)	5.27 (199.3)
Planting of maize + field pea (1:1)	5.29 (198.8)	4.19 (65.6)	4.48 (90.8)	4.39 (80.0)	5.24 (193.9)	4.16 (63.9)	4.55 (94.2)	4.41 (84.4)
Paired planting of maize (30/60 cm) + field pea (2:2)	5.16 (174.0)	4.04 (56.0)	4.33 (75.6)	4.36 (78.0)	5.13 (168.6)	3.97 (52.4)	4.31 (75.9)	4.38 (82.9)
	CD at 5%				CD at 5%			
Comparison between two planting patterns at same weed management	0.23 (38.9)				0.32 (43.8)			
Comparison between two weed managements at same planting pattern	0.25 (39.9)				0.38 (54.6)			

* Original values are in parentheses and values outside the parenthesis are log (x+1) transformed; DAS: days after sowing; PE: pre emergence; POE: post emergence

arrangement. Reduction in the grain yield of urdbean (Upasani *et al.*, 2000) and common bean (Maingi *et al.*, 2000) when intercropped with maize has also been reported. On an average, hand weeding (30 DAS), PE application of pendimethalin 1 kg ha^{-1} and POE application of imazethapyr 50 g ha^{-1} (30 DAS) yielded 50.8, 31.6 and 24.0 per cent higher yield over weedy check respectively. The higher grain yield in these treatments could be attributed to improvement in growth and yield components which was the result of lower crop-weed competition, which shifted the balance in favor of crop in the utilization of nutrients, moisture, light and space. Similar findings were reported by Mundra *et al.* (2003). The increased yield during 2011-12 than in 2012-13 growing season could be attributed to the greater competitive ability of field pea during that growing season as a result of the favorable weather condition. During 2012-13, there was frost in the month of January-February thereby extending the cold period which resulted yield reduction.

Straw yield of field pea : On an average, increased in straw yield in sole planting of field pea than planting of maize + field pea (1:1) and paired planting of maize (30/60 cm) + field pea (2:2) was 18.0 and 27.9 per cent respectively (Table 7). This was mainly due to higher plant population in sole planting of field pea. Similar results were reported by Mandal *et al.* (2014a) who reported significantly lower straw yield of intercropped soybean and groundnut than in monocropping. On an average, hand weeding (30 DAS), pre emergence application of pendimethalin 1 kg ha^{-1} and post emergence application of imazethapyr 50 g ha^{-1} (30 DAS) yielded 12.6, 5.0 and 6.1 per cent higher straw yield over weedy check respectively.

Baby corn yield : The yield of baby corn under different planting patterns was statistically similar during both the years (Table 7). The results of the present investigation are in accordance with those of Mandal *et al.* (2014b) who found that maize crop produced the highest grain yield in sole cropping which was statistically at par with intercropping situations like maize + soybean (1:2) and maize + groundnut (2:4). On an average, hand weeding (30 DAS), PE application of pendimethalin 1 kg ha^{-1} and POE application of imazethapyr 50 g ha^{-1} (30 DAS) yielded 72.6, 67.2 and 45.5 per cent higher baby corn yield over weedy check respectively. The higher baby corn yield in hand weeding (30 DAS) and herbicide treated plots were due to better growth and development of baby corn plants as a result of less competition from weeds for light, water, nutrients, carbon dioxide *etc.* as a result of better control of weeds as indicated by low weed density. Presence of weeds reduces the photosynthetic efficiency, dry matter production and distribution to economical parts and there by reduces sink capacity of crop resulting in poor yield. The efficiency of chemicals and other weed control practices in increasing grain yield had also been demonstrated by Dixit (1995), Shinde *et al.* (2001), Khan *et al.* (2002) and Khan and Haq (2004).

Stover yield of baby corn : On an average, sole planting of baby corn yielded 123.1 and 97.3 per cent more stover yield over planting of maize + field pea (1:1) and paired planting of maize (30/60 cm) + field pea (2:2) respectively (Table 7). This was mainly due to better growth and dry matter accumulation in sole planting of baby corn. Similar results were reported by Mandal *et al.* (2014a) who reported that sole maize produced significantly higher stover yield than all other intercropping treatments with groundnut. Among the weed management practices, on an average, hand weeding (30 DAS), PE application of pendimethalin 1 kg ha^{-1} and POE application of imazethapyr 50 g ha^{-1} (30 DAS) yielded 33.3, 39.2 and 3.5 per cent higher stover yield over weedy check respectively. More stover yield in weed control treatments than weedy check was due to less weed density and better growth and development of baby corn plant. These results are in close agreement with Sinha *et al.* (2001), Dixit and Gautam (1996) and Shinde *et al.* (2001) who found that use of herbicides to control weeds resulted in increased plant height, plant population and stover yield.

Table 7. Effect of planting patterns and weed management practices on grain and straw yields of field pea and baby corn and stover yield of baby corn during 2011-12 and 2012-13

Treatment	Field pea yield (kg ha^{-1})						Baby corn (kg ha^{-1})					
	Grain			Straw			Baby corn			Stover		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Planting pattern												
Field pea sole (30 cm)	2264	1434	1849	3263	2540	2902	-	-		-	-	
Baby corn sole (45 cm)	-	-		-	-		812	810	811	3576	3533	3555
Planting of maize + field pea (1:1)	1108	888	998	2885	2032	2459	792	733	763	1615	1572	1594
Paired planting of maize (30/60 cm)+field pea (2:2)	1528	764	1146	2592	1946	2269	807	746	777	1823	1780	1802
CD at 5%	229	168	-	312	242	-	NS	NS	-	136	278	-
Weed management												
Weedy	1268	835	1052	2754	2047	2401	684	387	536	1968	1925	1947
Hand weeding (30 DAS)	1947	1225	1586	3108	2298	2703	952	896	924	2616	2573	2595
Pendimethalin 1 kg ha^{-1} (PE)	1700	1068	1384	2849	2194	2522	801	990	896	2731	2688	2710
Imazethapyr 50 g ha^{-1} (POE, 30 DAS)	1620	987	1304	2943	2152	2548	778	780	779	2037	1994	2016
CD at 5%	113	106	-	184	102	-	69	25	-	206	130	-

DAS: days after sowing; PE: pre emergence; POE: post emergence; NS: non significant

CONCLUSION

In the light of the two years experimental results, it may be concluded that sole planting gave more crop yield but both the intercropping systems had more weed suppression capacity than sole planting of either field pea or baby corn. Hand weeding at 30 DAS proved more efficient as compared to PE application of pendimethalin 1 kg ha^{-1}, POE application of imazethapyr 50 g ha^{-1} (30 DAS) and weedy check.

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Residual soil fertility and nutrient uptake in baby corn as influenced by nutrient sources and weed control measures

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ABSTRACT

A field experiment was conducted at Indian Agricultural Research Institute, New Delhi to assess the effect of nutrient sources and weed control measures on nutrient uptake, yield and residual soil fertility after harvest of baby corn. The highest husked and dehusked baby cob yields (4.43 t ha^{-1} and 2.15 t ha^{-1}, respectively) and green fodder yield were obtained with application of N through vermicompost and the lowest (3.30 and 1.80 t ha^{-1}, respectively) was recorded with the application of N through fertilizer. Residual fertility in terms of available N, P and K (186.5, 18.0 and 208.2 kg ha^{-1}) in the soil after crop harvest was significantly superior when 120 kg N ha^{-1} was applied through FYM in comparison with recommended dose of N applied through fertilizer and it was at par with leaf compost and vermicompost. In case of weed control measures, the highest husked and dehusked cob yield (4.29 t ha^{-1} and 2.18 t ha^{-1} respectively) and green fodder yields were found in weed free treatment and the lowest values were obtained from unweeded control (3.05 t ha^{-1} and 1.68 t ha^{-1} respectively). Available N, P, K, bulk density and organic carbon in soil was not significantly varied due to weed control measures.

Key words: Baby corn, nutrient uptake, residual soil fertility, yield

Maize is the third most important cereal crop of India as well as the world. It is used both as food for human and feed for livestock especially poultry industry. In late 1970's people in USA and western countries started to consume raw cobs called baby corn. Though the baby corn is more popular worldwide, agro-techniques to achieve higher production is the need of the day (Thavaprakaash *et al.* 2005). Baby corn being a rich source of phosphorus, iron, vitamin A and C, high fiber concentration and no cholesterol gained popularity as a vegetable (Thakur, 2000). Though the baby corn is quite popular worldwide, systematic development of agro-techniques particularly nutrient management to achieve higher production in India is the need of the day (Sobhana *et al.* 2012). The applied nutrients may not be helpful in increasing the productivity of maize until unless other constraints like competition offered by weeds is removed with suitable method (Barod *et al.*, 2012). Owing to congenial weather condition and wider row spacing maize suffers heavily due to severe weed infestation (Malviya and Singh, 2007). Yield loss due to weeds in maize (*Zea mays* L.) varies from 28-93%, depending on the type of weed flora and the intensity and duration of crop-weed competition. Maize crop is very much sensitive to weed competition between 20 to 40 days after sowing (Varshney, 1991). Therefore, it is necessary to adopt a suitable weed control measure to reduce the yield loss due to weed competition. In view of the above, the present investigation has been carried out to assess the effect of nutrient sources and weed control measures on growth, yield and quality of baby corn.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2008 at the Experimental Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The soil of experimental field was sandy loam in texture, poor in organic carbon, low in available N (162 kg ha^{-1}), medium in available P (16.2 kg ha^{-1}) and K (198.2 kg ha^{-1}) and neutral in reaction (pH 7.6). Crop received 342.8 mm precipitation in 17 rainy days. The experiment was laid out in a factorial randomized block design and replicated thrice with the combination of 4 nutrient sources: 120-26.4-41.7 kg N-P-K ha^{-1} through fertilizers, 120 kg N through FYM, 120 kg N through leaf compost and 120 kg N through vermicompost; and 4 weed management practices: unweeded control, weed free check, two hand weeding at 20 and 40 days after sowing (DAS) and application of atrazine @ 0.5 kg and pendimethalin @ 0.75 kg ha^{-1} tank mixed as pre emergence (PE). Baby corn variety 'PEHM 2' was sown on the ridges spaced at 60 cm using 20 kg seed ha^{-1}. The N, P and K uptake by Plant was calculated by multiplying dry matter yield ha^{-1} with corresponding values of their concentration divided by 100 and were expressed as kg ha^{-1}. Zn and Fe uptake was calculated by multiplying the straw and baby corn yield with their respective Zn and Fe concentration.

RESULTS AND DISCUSSION

Yield

Cob yield : The husked cob yield was significantly higher for application of N through vermicompost (4.43 t ha^{-1}) as compared to its application through FYM (3.80 t ha^{-1}) or leaf compost (3.67 t ha^{-1}) or fertilizer (3.30 t ha^{-1}) (Table 1). Application of N through vermicompost (2.15 t ha^{-1}) being at par with N application through FYM (2.09 t ha^{-1}) and leaf compost (2.01 t ha^{-1}) produced significantly higher yield of dehusked cob as compared to application through fertilizer (1.80 t ha^{-1}). Among the weed management practices, husked cob yield was significantly higher for weed free treatment (4.29 t ha^{-1}) as compared to remaining weed management practices. The highest dehusked cob yield (2.18 t ha^{-1}) was also recorded in weed free treatment and significantly lower value was found in unweeded control (1.68 t ha^{-1}). This higher cob yield in weed free treatment was due to lack of competition for different growth factors between baby corn and weeds.

Green fodder yield : Application of N through vermicompost being at par with N application through FYM and leaf compost produced significantly higher green fodder yield than N application through fertilizer (Table 1). Weed free treatment being at par with two hand weeding

Table 1. Effect of nutrient sources and weed control measures on cob and green fodder yield

Treatment	Yield (t ha^{-1})		
	Cob		Green fodder
	Husked	Dehusked	
Nutrient sources			
120-26.4-41.7 kg N-P-K ha^{-1} through fertilizers	3.30	1.80	21.50
N through FYM	3.80	2.09	27.27
N through leaf compost	3.67	2.01	26.14
N through vermicompost	4.43	2.15	28.05
CD (P=0.05)	0.32	0.24	4.62
Weed control measures			
Unweeded control	3.05	1.68	21.07
Weed free check	4.29	2.18	30.22
Two hand weeding at 20 & 40 DAS	3.92	2.08	26.32
Tank mixed Atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE	3.94	2.09	25.75
CD (P=0.05)	0.32	0.24	4.62

Table 2. Effect of nutrient sources and weed control measures on N, P, K, Zn and Fe uptake in baby corn cob and stover

Treatment	Baby corn cob					Stover					Total				
	kg ha^{-1}			g ha^{-1}		kg ha^{-1}			g ha^{-1}		kg ha^{-1}			g ha^{-1}	
	N	P	K	Zn	Fe	N	P	K	Zn	Fe	N	P	K	Zn	Fe
Nutrient sources															
120-26.4-41.7kg N-P-K ha^{-1} through fertilizers	5.48	1.36	8.7	15	500	57.22	10.48	92.6	218	8300	62.7	11.84	101.3	233	8800
N through FYM	6.99	1.67	11.1	20	736	62.2	11.23	107.3	316	9920	69.22	12.9	118.42	336	10656
N through leaf compost	6.15	1.47	9.5	16	627	61.0	11.04	103.1	269	8970	67.16	12.51	112.71	285	9597
N through vermicompost	7.39	1.72	10.6	21	757	64.6	11.45	109.9	271	10080	71.97	13.17	120.52	292	10837
CD (P=0.05)	1.10	0.29	2.14	3.0	124	6.00	NS	17.08	50	1190					
Weed control measures															
Unweeded control	4.49	1.15	7.5	13	484	53.9	8.56	91.4	209	7940	58.37	9.71	99.02	222	8424
Weed free check	7.60	1.81	11.7	21	774	66.5	12.69	109.4	323	11080	74.08	14.5	121.17	344	11854
Two hand weeding at 20 & 40 DAS	6.79	1.68	10.2	20	725	61.3	11.63	104.1	271	9470	68.12	13.31	114.41	291	10195
Atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE	7.12	1.62	10.4	20	641	61.2	11.29	105.2	272	9070	68.35	12.91	115.7	292	9711
CD (P=0.05)	1.10	0.29	2.14	3.0	124	6.00	1.73	17.08	50	1190					

at 20 and 40 DAS and tank mixed atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE recorded significantly higher green fodder yield than unweeded control.

N, P, K, Zn and Fe uptake in baby corn cob and stover

N,P, Zn and Fe uptake in baby corn cob was significantly higher when N was applied through vermicompost over recommended dose of NPK applied through fertilizers and N through leaf compost; however it was at par with N applied through FYM. K uptake in baby corn was significantly higher when N was applied through FYM over recommended dose of NPK applied through fertilizers (Table 2). However, Pawar and Patil (2007) obtained maximum uptake of major and micro-nutrients in maize with combined application of vermicompost and RDF through fertilizers. Among the weed control measures significantly higher N, P, K, Fe and Zn uptake in baby corn cob was recorded from weed free check over unweeded control and it was at par with two hand weeding at 20 and 40 DAS and atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE (Table 2). Weed free condition facilitated higher uptake of nutrients than the control treatment owing to increase in nutrient availability in soil due to early elimination of weed competition and better crop growth and higher assimilate accumulation in plant Malviya and Singh (2007). N uptake in baby corn stover was significantly higher when N was applied through vermicompost over recommended dose of NPK applied through fertilizers; however, it was at par with N applied through FYM or through leaf compost. Similar trends were observed in case of P, K, Zn and Fe uptake in baby corn stover except that the treatment where N was applied through FYM gave significantly higher values of P and Fe uptake than the recommended dose of NPK applied through fertilizers. The uptake of N, P, K, Zn and Fe in baby corn stover was maximum in weed free check treatment and it was at par with two hand weeding (20 and 40 DAS) and application of atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE.

Total uptake of N, P, K, Zn and Fe in baby corn plant

Total N uptake in baby corn plant was relatively higher when N was applied through vermicompost over recommended dose of NPK applied through fertilizers; however, it was similar with N applied through FYM or through leaf compost. Similar trends were observed in case of P, K, and Fe uptake. Zn uptake was relatively higher when N was applied through

Table 3. Effect of nutrient sources and weed control measures on bulk density, organic carbon, available nitrogen, phosphorus and potassium in soil (0-15 on depth) after crop harvest

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Bulk density (Mg m^{-3})	O C (%)
Nutrient sources					
120-26.4-41.7 kg N-P-K ha^{-1} through fertilizers	156.9	15.49	188.00	1.56	0.31
N through FYM	186.5	17.97	208.16	1.56	0.35
N through leaf compost	176.3	17.17	207.15	1.57	0.35
N through vermicompost	170.2	16.86	201.53	1.57	0.34
CD (P=0.05)	24.8	1.70	15.70	NS	NS
Weed control measures					
Unweeded control	169.3	16.62	196.46	0.56	0.33
Weed free check	172.7	17.17	198.06	0.56	0.35
Two hand weeding at 20 & 40 DAS	172.2	16.98	199.85	0.57	0.32
Atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE	174.5	16.72	194.39	0.57	0.35
CD (P=0.05)	NS	NS	NS	NS	NS

FYM and lower in recommended dose of NPK applied through fertilizers (Table 2). The uptake of N, P, K, Zn and Fe in baby corn plant was maximum in weed free check treatment and it was similar with two hand weeding (20 and 40 DAS) and application of atrazine @ 0.5 kg and pendimethalin @ 0.75 kg ha^{-1} as PE. The lowest values of N, P, K, Zn and Fe in baby corn plant were recorded from unweeded control.

Available N, P, K, bulk density and OC in soil

Available N, P and K were significantly affected by nutrient sources while bulk density and organic carbon in soil were found unaffected by nutrient sources. Weed control measures did not showed any significant effect on these parameters. The available N, P and K in soil was significantly higher where N was applied through FYM in comparison with recommended dose of nutrients applied through fertilizers and it was at par with N applied through leaf compost or vermicompost (Table 3). It might be due to direct contribution toward the available nitrogen, phosphorus and potassium pool of soil and decomposition of the organic material leads to enhancement of N, P and K status in soil (Pawar and Patil, 2007). Available N, P, K, bulk density and OC in soil was not significantly varied due to weed control measures.

CONCLUSION

Based on the above results it may be concluded that highest quality produce in terms of N, P, K, Zn, Fe, protein and sugar concentration may be obtained with the application of 120 kg N through vermicompost followed by same amount of N through FYM. In weed control measures two hand weeding at 20 & 40 DAS or application of atrazine @ 0.5 kg + pendimethalin @ 0.75 kg ha^{-1} as PE were equally effective as weed free check in respect to yield and quality of baby corn and green fodder. All organic sources were found better in terms of available N, P and K in soil after crop harvest than fertilizers.

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Impact of integrated nutrient management on growth and economics of maize (*Zea mays* L.)

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Abstract

Increased food production, a boon of green revolution had led the country to a state of self sufficiency and pulled the country out of the ship to mouth existence. Among the various food crops cereals namely rice and wheat have been under the main focus of this revolutionary progress. However, maize, the queen of cereals occupies a pride place among cereal crops in India, emerged as third most important food crop after rice and wheat as it represents 9.92 per cent of total cereal production. It is a staple food for vast rural population of our country. Maize is cultivated in diverse production environments ranging from temperate hill zone of Himachal Pradesh to the semi arid region of Rajasthan. Amongst the growth inputs, mineral nutrients play a vital role not only in exploiting the realizable potential of the crop but also to maintain sustainability of soil for agricultural production. An exhaustive review of the nutrient balance sheet of Rajasthan agriculture reveals that constant mining of nutrient elements through crops and subsequent insufficient addition of these nutrients to the soil in the form of manures and fertilizers has tilted it in a negative balance (Gupta, 2001).

Key words: Economics, growth, integrated, maize and nutrient management

An investigation was carried out during *kharif*, 2011 at College of Agriculture, Udaipur to assess the effect of continuous application of plant nutrients through organic and inorganic sources and its combination on plant height, leaf area index and economics of maize. The twelve treatments, *viz.*, 100% NPK, 100% NPK+Zn, 100% NPK+Zn+S, 100%NPK+S, 100%NPK+seed treatment with *Azotobacter*, FYM 10 t ha^{-1}+100% NPK(-NPK of FYM), 100% NPK+FYM 10 t ha^{-1}, FYM 20 t ha^{-1}, 150% NPK, 100% NP, 100% N and absolute control were replicated four times in randomized block design

The sources used for applying N, P and K were urea, di-ammonium phosphate (adjusted for its N content) and muriate of potash, respectively. Gypsum and zinc sulphate ($ZnSO_4.H_2O$) were used to supply S and Zn. The other sources of nutrients were FYM (farm yard manure) and biofertilizer (*Azotobacter* sp.). The dose of the NPK for maize was worked out according to the soil test fertilizer recommendation. The 100% NPK dose in kg ha^{-1} worked out was 120: 60: 30 for maize crop. The doses for sulphur and zinc were framed as 40 kg S ha^{-1} and 5 kg Zn ha^{-1}, respectively while FYM was applied as per the treatments. Maize variety PEHM-2 was sown at the seed rate of 25 kg ha^{-1} at inter row spacing of 60 cm and plant to plant spacing of 20 cm. Statistical analysis of the data was carried out using standard analysis of variance (Panse and Sukhatme, 1989).

The data (Table 1) show that application of plant nutrient through inorganic and organic sources and their integrated use resulted in significant increase in plant height of plants at 45 DAS in comparison to control. Maximum plant height was obtained by 100% NPK + FYM 10 t

Table 1. Effect of integrated nutrient management on plant height, leaf area per plant (LAPP) and LAI of maize

	Plant height (cm)			Leaf area per plant (cm^2)			LAI		
Treatment	45 DAS	60 DAS	Harvest	45 DAS	60 DAS	Harvest	45 DAS	60 DAS	Harvest
100% NPK	132.6	172.8	192.5	3393.0	3747.3	2874.0	2.83	3.12	2.40
100% NPK+Zn	130.5	174.4	193.7	3604.0	4080.4	3127.1	3.00	3.40	2.61
100% NPK+S+Zn	127.0	171.4	194.3	3637.7	4192.1	3411.5	3.03	3.49	2.84
100% NPK+S	129.0	170.1	189.4	3372.0	3755.7	2937.4	2.81	3.13	2.45
100% NPK+ *Azotobacter*	126.5	169.9	191.8	3490.5	4134.2	3139.9	2.91	3.45	2.62
FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	129.1	170.4	192.9	3420.5	4069.4	3302.4	2.85	3.39	2.75
100% NPK + FYM 10 t ha^{-1}	135.2	178.6	202.3	3849.2	4359.2	3529.5	3.21	3.63	2.94
FYM 20 t ha^{-1}	119.2	153.7	170.6	3037.3	3445.8	2806.8	2.53	2.87	2.34
150 % NPK	133.9	176.0	201.6	3821.7	4260.8	3588.1	3.18	3.55	2.99
100% NP	121.9	154.7	177.1	3321.6	3449.1	2768.6	2.77	2.87	2.31
100 % N	121.0	149.7	163.4	2907.5	3206.7	2589.2	2.42	2.67	2.16
Control	91.0	118.6	131.8	2092.8	2372.2	1954.0	1.74	1.98	1.63
S.Em. ±	3.20	3.54	3.48	43.53	76.70	78.95	0.04	0.06	0.07
C.D. (P = 0.05)	9.23	10.20	10.03	125.47	221.07	227.57	0.10	0.18	0.19

ha^{-1} (135.3 cm). The crop under balanced and integrated fertilization recorded significantly higher plant height of maize crop at 60 DAS over unfertilized control. Application of 100% NPK + FYM 10 t ha^{-1} resulted in maximum plant height (178.63 cm). However, its results was at par with 150% NPK, 100% NPK+Zn, 100% NPK, 100% NPK+S+Zn, FYM 10 t ha^{-1}+ 100% NPK(-NPK of FYM), 100% NPK+ S and 100% NPK+*Azotobacter* seed treatment. At harvest perusal of data indicates that variation in plant height ranged from 131.9 cm to 202.4 cm during the course of experimentation and the maximum plant height, (202.35 cm) was observed by applying 100% NPK + FYM 10 t ha^{-1}.

The crop under balanced and integrated fertilization recorded significantly higher leaf area per plant (LAPP) of maize compared to no fertilization (Table 1). At 45 DAS addition of plant nutrients through fertilizers, organic sources and their combination proved efficient in enhancing LAPP of maize plant at 45 DAS. Maximum LAPP (3849.3cm^2) was recorded by applying 100% NPK + FYM 10 t·ha^{-1}, which was at par to 150% NPK. The magnitude of increase in leaf area per plant due to different nutrients management ranged from 814.8 to 1756.5 cm. At 60 DAS among various treatments, maximum leaf area per plant was recorded under effect of 100% NPK + FYM 10 t ha^{-1}, which brought 83.7 per cent increase in LAPP at 60 DAS over control. A further insight in to figures reveal that application of 100% NPK+S +Zn and 150% NPK were at par with 100% NPK + FYM 10 t ha. At harvest highest LAPP (3588.2 cm^2) was found in treatment receiving 150% NPK at harvest. Its result was at par to100% NPK+FYM 10 t ha^{-1} and 100% NPK + S + Zn. The leaf area per plant at harvest varied between 1954.1 to 3588.2 cm^2.

Compared to control, application of 100% N recorded significantly higher LAI at 45 DAS, while balancing the fertilization with P, K, S and Zn or integrating NPK with FYM or bio-fertilizer accounted further enhancement in LAI. Among various combinations, highest LAI (3.21) was obtained by application of 100% NPK and FYM 10 t ha^{-1} (Table 1). The data further indicate that nutrient application in various forms and FYM combinations tended to result in significantly higher LAI at 60 DAS which varied from 1.98 to

Table 2. Effect of integrated nutrient management on grain yield and economics of maize

Treatments	Grain yield (q ha^{-1})	Net return (₹ ha^{-1})	B C ratio
100% NPK	31.94	27,622	1.79
100% NPK + Zn	32.90	28,062	1.66
100% NPK + S + Zn	34.87	30,313	1.81
100% NPK + S	32.74	28,248	1.78
100% NPK + *Azotobacter*	33.77	30,021	1.94
FYM 10 t ha^{-1} + 100% NPK (–NPK of FYM)	34.40	29,450	1.73
100% NPK + FYM 10 t ha^{-1}	39.12	34,107	1.85
FYM 20 t ha^{-1}	23.64	13,209	0.71
150 % NPK	36.98	33,101	1.96
100% NP	27.79	22,330	1.47
100 % N	21.37	14,968	1.07
Control	12.85	4,714	0.37
S.Em. ±	1.05	1,444	0.09
C.D. (P = 0.05)	3.04	4,163	0.26

3.63. The highest LAI (3.63) was recorded by enriching the soil with 100% NPK + FYM 10 t ha^{-1} which was significantly superior over all other treatments. Application of 150% NPK followed the order of significance. However, its effect was at par with100% NPK + Zn, 100% NPK + S + Zn,100%NPK+*Azotobacter* and FYM 10 t ha^{-1} + 100% NPK (–NPK of FYM). It is obvious from data that maximum LAI at harvest of maize during experimentation was observed under 150% NPK (2.99). The treatment next in order of significance was 100% NPK + FYM 10 t ha^{-1}.

Application of integrated nutrient management as 100% NPK + FYM 10 t ha^{-1} recorded maximum grain yield and its performance was at par with 150% NPK (Table 2). The treatment receiving 100% NPK and its combination with Zn, S, Zn+S, *Azotobacter* seed treatment and FYM 10 t ha^{-1} + 100% NPK (–NPK of FYM) showed statistically equivalent results. Though application of 100% N, 100% NP and FYM 20 t ha^{-1} increased the grain yield significantly over control but provided inferior results in comparison to aforesaid treatments. Economic evaluation of treatments indicates (Table 2) that application of 100% NPK + FYM 10 t ha^{-1} gave highest net return (₹ 34107) which was at par to that obtained by application of 100% NPK in combination with Zn + S or Seed treatment with *Azotobacter* and 150% NPK. It is evident from data (Table 4) that highest B C ratio (1.96) was obtained by applying 150% NPK, which was at par with 100% NPK + FYM 10 t ha^{-1}, 100% NPK either alone or in combination with S or S+Zn or seed treatment with *Azotobacter*, and FYM 10 t ha^{-1} + 100% NPK (–NPK of FYM).

The significant effects of these parameters as a consequence of balanced fertilization and its integration with organic manure to maize crop are attributed to the favorable nutritional status of soil resulting into enhanced growth parameters *viz.*, plant height, LAI, and leaf area per plant (LAPP) that resulting into increased photosynthetic area and biomass production of the crop Table 1. Organic manure also improve microbial activity and root proliferation in soil which caused solubilizing effect on native phosphorus and other nutrients. However, as fertilizer dose increased, the beneficial effects decreases because due to excessive use of fertilizers resulting in over exploitation of nutrients particularly micronutrients. The results of combined use of fertilizers and FYM are in close agreement with the findings of Panwar, 2008; Dadarwal *et al.*, 2009; Singh *et al.*, 2009; Jat *et al.*, 2013.

Based upon the results, it may be concluded that maize should be supplied with 100% NPK based on soil test in conjunction with 10 t ha^{-1} of FYM for better development of growth parameters, productivity and economic returns.

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Effect of phosphorus rich compost with and without PSB and vermiculture on growth, yield and economics of maize (*Zea mays* L.)

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ABSTRACT

Field experiment was conducted during *kharif* 2013 on clay loam soil of Instructional Farm, Rajasthan College of Agriculture, Udaipur, to study the effect of phosphorus rich compost with and without PSB and vermiculture on growth, yield and economics of maize. The experiment was conducted in a completely randomized block design with factorial arrangement with three replications. Treatments included: control, 100% RDP through DAP; 100% RDP through SSP; 25% RDP through PRC + 75% RDP through DAP; 25% RDP through PRC+PSB + 75% RDP through DAP; 25% RDP through PRC + vermiculture + 75% RDP through DAP; 25% RDP through PRC + PSB + vermiculture + 75% RDP through DAP; 100% RDP through PRC; 100% RDP through PRC+PSB; 100% RDP through PRC+ vermiculture and 100% RDP through PRC + vermiculture + PSB. Among phosphorus sources, DAP, SSP and PRC incubate with and without PBS and vermiculture, application of 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP, significantly improved plant height, dry matter, average cob length, no. of grains cob, weight of cob, test weight, grain yield, stover yield, net return and B: C ratio of maize crop over other treatments. However, it was statistically at par with treatment having 100% RDP through DAP, 100% RDP through SSP, 25% RDP through PRC + 75% RDP through DAP, 25% RDP through PRC + vermiculture + 75% RDP through DAP, 100% RDP through PRC+PSB and 100% RDP through PRC + vermiculture + PSB.

Key words: Growth, Maize, Net return, Phosphorus rich compost, PSB, Vermiculture, Yield.

Maize (*Zea mays* L.) is an important cereal crop of India and plays a pivotal role in agricultural economy both as staple food for larger section of population, raw material for industries and feed for animals (mostly poultry). In India, maize occupying 8.71 m ha area, 21.57 mt production and 2476 kg/ha productivity (Anonymous, 2012). The productivity is quite lower than other developed countries mainly due to sub-optimal application of fertilizers and its cultivation on marginal lands. The phosphorus rich compost (PRC) being cheaper and eco-friendly and could be the alternatives of chemical fertilizers for improving both crop productivity and sustainability of the systems. The total rock phosphate deposits in India are estimated to be about 300 million tonnes (TIFAC, 2011) of which only a fraction of it (about 25%) meets the specification of the fertilizer industry because of low grade P content (low grade). In Rajasthan, major sources of rock phosphate are Jhamarkotra (Udaipur) rock phosphate which contains both low as well as high grade rock phosphate and locally available source of phosphorus. Rock phosphate has good P content (28-30%) but cannot be used directly as a fertilizer because of its poor release of P for the use of plant (Reddy *et al.*, 2002). Rock phosphate is effective when applied directly to acidic soils. It cannot be used with the same levels of efficiency on alkaline calcareous soils. In alkaline soils of India, direct use of RP is not feasible because of its poor solubility. However, if RP is allowed to react with organic acids produced during composting, a major part of RP-P could be solubilizes for plant uptake (Singh and Reddy, 2011). The interaction of organic acids released during composting results in P solubilization from RP for plant uptake. The use of organic fertilizers made up of various composted materials, is now established as a key strategy not only for improving soil organic matter content and nutrient supply to plants but also for reducing the input cost of mineral fertilizers and promoting healthier environments (Ahmad *et al.*, 2006). Therefore, the availability of phosphorus from these rock phosphate could be improved through composting technology using FYM, agricultural wastes, crop residues, phosphate solubilizing bacteria (PSB) and earthworm (Vermicompost) to make available 'P' in alkaline soils. This may imply that the low grade RP reserves of India could be used efficiently by preparing phosphate rich compost which would not only be economical but also be environment friendly. Therefore, the present study was carried out to study the effect of phosphorus rich compost with and without PSB and vermiculture on growth, yield and economics of maize crop.

MATERIALS AND METHODS

The experiment was conducted at the Instructional Farm, Rajasthan College of Agriculture, Udaipur during *Kharif* 2013. The site is situated at South-Eastern part of Rajasthan at an altitude of 579.5 m above mean sea level, at 24°35' N latitude and 74°42' E longitude. The soil was sandy clay loam, slightly alkaline (pH 7.78), medium in OC (0.62%), N (262 kg ha), P_2O_5 (20.5 kg ha) and high in K_2O (432 kg ha) and sufficient amount of DTPA extractable micronutrients. The experiment was laid out in randomized complete block design with three replications along with eleven treatments Control; 100% RDP through DAP; 100% RDP through SSP; 25% RDP through PRC + 75% RDP through DAP; 25% RDP through PRC + PSB + 75% PDP through DAP; 25% RDP through PRC + vermiculture + 75% PDP through DAP; 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP; 100% RDP through PRC; 100% RDP through PRC + PSB; 100% RDP through PRC + vermiculture; and 100% RDP through PRC + vermiculture + PSB. The field was prepared by cross cultivator followed by planking to obtain well pulverized soil tilth. During sowing 50% of total dose of N and full dose of P_2O_5 and K_2O were applied as basal and remaining 50% in 25-30 DAS. The maize (*cv.* PEHM-2) was sown manually in furrow maintaining the optimum plant spacing of 60x20 cm. However, all the other intercultural operations were done as per need of crop. The observations on growth parameters and yield of maize were recorded at harvest. In order to evaluate the economic feasibility of different treatments, the economics was worked out in terms of net profit per hectare by taking into account the market prices of chemicals, labour and other inputs so that the remunerative treatments could be work out for recommendations. The data collected was analyzed statistically using Fisher's analysis of variance technique and individual treatment means were separated using least significant difference (RBD) test at 5 percent probability level.

For the preparation of P rich compost, four pits of six feet length, three feet width and two feet depth were made. Raw materials like farm wastes and fresh cow dung were collected and mixed in the ratio of 1:1 on dry weight basis. Low grade rock phosphate (16% P_2O_5) was procured from Rajasthan State Mines and Minerals Ltd., Udaipur, Rajasthan. The pits were filled with crop residue; FYM and Jhhamarkotra rock phosphate in the ratio of 10:1, respectively and mix them well. The mixed material was filled to all the four pits, and finally water was added for better composting. After twenty days of composting, earthworms and phosphate solubilizing bacteria were released in the respective pits having treatment of vermiculture and PSB. The organic material was composted and vermicomposted for three months and all pits were kept moist throughout the composting period.

Results and Discussion

Growth and yield attributes

Application of phosphorus rich compost influenced the growth (plant height, dry matter) and yield attributes (average cob length, no. of grain cob, cob weight and test weight) significantly over control (Table 1). The maximum plant height (206.73 cm), dry matter (164.67 g plant), average cob length (16.87 cm), no. of grains cob (391.00 grain cob), cob weight (134.67 g) and test weight (197.0 g) were recorded under application of 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP. Application of 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP significantly increased plant height and dry matter yield over control and rest of treatments. However, it was statistically at par with application of 100% RDP through DAP, 100% RDP through SSP, 25% RDP through PRC + PSB + 75% PDP through DAP, 25% RDP through PRC + vermiculture + 75% PDP through DAP, 100% RDP through PRC + PSB and 100% RDP through PRC + vermiculture + PSB. The increase in growth and yield characteristics is attributed to the stronger role of P in cell division, cell expansion and enlargement which ultimately affect the vegetative growth of maize. Opala *et al.* (2009) reported that integrated application organic and inorganic phosphorus sources had significant positive role in the growth characteristics of maize. Further, application of chemical fertilizers with phosphorus rich compost (incubate with PSB and Vermiculture) increased the growth parameters over control. It was due to improved physico-chemical properties of soil and provides a better soil environment for the biological activity and improved microbial population of the experiment soil and also supplies micronutrient which beneficial to the crop growth and productivity. Increasing organic matter in soil to microbial decomposition leading to production of H_2CO_4 and other organic acid this might have reduce pH and lead to increase availability of P and other nutrients to crop plants for proper growth and development. The results of the present investigation are in agreement with the findings by several researchers Vyas *et al.* (2012), Hellal *et al.* (2013) and Sepat and Rai (2013).

Yield and economics

The grain and stover yield of maize affected

Table 1. Effect of phosphorus rich compost on growth and yield attributes of maize.

Treatments	Plant height (cm)	Dry matter (g plant)	Average cob length (cm)	No. of grains/ cob	Weight/ cob (g)	Test weight (g)
Control	151.0	123.2	13.2	288.3	93.6	157.6
100% RDP through DAP	187.3	152.7	15.6	376.7	129.6	187.4
100% RDP through SSP	185.6	150.1	15.8	372.0	127.3	186.0
25% RDP through PRC + 75% RDP through DAP	180.9	140.3	14.6	362.3	120.1	181.3
25% RDP through PRC + PSB + 75% RDP through DAP	194.0	158.0	16.8	385.3	131.0	193.9
25% RDP through PRC + Vermiculture + 75% RDP through DAP	189.9	155.0	15.7	380.7	128.7	187.4
25% RDP through PRC + Vermiculture + PSB + 75% RDP through DAP	206.7	164.7	16.9	391.0	134.7	197.0
100% RDP through PRC	178.3	142.1	13.6	360.7	119.8	178.6
100% RDP through PRC + PSB	184.8	146.0	14.7	365.7	122.4	184.4
100% RDP through PRC + Vermiculture	181.5	142.0	14.5	363.7	120.9	181.9
100% RDP through PRC + Vermiculture + PSB	187.0	149.3	15.7	370.7	125.0	188.2
SEm±	8.1	7.1	0.4	9.1	4.4	4.6
CD (P = 5%)	23.9	21.1	1.3	26.9	12.8	13.5

by the application of phosphorus rich compost is given in Table 2. Significantly increased in grain, stover and net return of maize were obtained with 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP followed by 25% RDP through PRC + PSB + 75% RDP through DAP. The maximum grain yield (3.93 t ha), stover yield (5.74 t ha), net return (38337 Rs ha) and B:C ratio (2.19) were recorded under application of 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP and lowest grain yield (1.89 t ha), stover yield (3.14 t ha), net return (14611 Rs ha) and B:C ratio (1.14) were noted in control where phosphorus rich compost was not applied. The application of 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP increased the grain and stover yield by 107.5% and 82.6%, respectively over the control (Table 2) which could be due to the increased availability of P through PRC, as besides acting as a source of nutrients. Application of 100% RDP through DAP, 100% RDP through SSP, 25% RDP through PRC + PSB + 75% RDP through DAP, 25% RDP through PRC + vermiculture + 75% RDP through DAP, 100% RDP through PRC + PSB and 100% RDP through PRC + vermiculture + PSB were at par for their effect on grain yield, stover yield and economics of maize. Maximum yield response (107.5%) was recorded with 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP followed by 25% RDP through PRC + PSB + 75% RDP through DAP (95.7%). The results indicate that grain yield is the function of yield attributes which are dependent on source and sink relationship. The overall improvement in yields attributes with 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP resulted in realization of higher production in terms of grain yield. It is well documented that P uptake by crop largely depends on dry matter accumulation and concentration of P in the plant parts at cellular level and increased availability of P in the soil due to solubilization of added phosphorus by P solubilizers through the production of organic acids. The results corroborate the findings of Mishra *et al.* (1982), attributing the effect of rock phosphate enriched compost to the release of P from rock phosphate during decomposition and partially the additive effect of organics. Also the organics enriched with inorganic P, when added to soil are subjected to biological mineralization and there is a production of organic-P fractions as phospho-humus complexes which easily supply nutrients to plants. Ali *et al.* (2014) who reported that grain and stover yield of maize was increased significantly by the application of Rock phosphate composted with organic materials. The results of the present investigation are in agreement with the findings by several

Table 2. Effect of phosphorus rich compost on yield and net returns of maize.

Treatments	Grain yield (t ha)	Stover yield (t ha)	Net returns (Rs ha)	B:C ratio
Control	1.89	3.14	14611	1.14
100% RDP through DAP	3.51	5.14	32126	1.82
100% RDP through SSP	3.44	5.07	31426	1.80
25% RDP through PRC + 75% RDP through DAP	3.30	4.95	28867	1.59
25% RDP through PRC + PSB + 75% RDP through DAP	3.71	5.48	34944	1.97
25% RDP through PRC + vermiculture + 75% RDP through DAP	3.59	5.37	33234	1.86
25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP	3.93	5.74	38337	2.19
100% RDP through PRC	3.32	4.89	27480	1.40
100% RDP through PRC + PSB	3.49	5.13	31570	1.75
100% RDP through PRC + vermiculture	3.40	4.96	29755	1.61
100% RDP through PRC + vermiculture + PSB	3.60	5.34	34499	2.06
SEm±	0.18	0.26	2265	0.13
CD (P = 5%)	0.52	0.77	6683	0.38

researchers Majumdar *et al.,* (2007), Hellal *et al.,* (2013) and Sepat and Rai (2013).

CONCLUSION

The results of present investigation indicated that application of 25% RDP through PRC + vermiculture + PSB + 75% RDP through DAP, is the better option for realizing higher productivity and economics of maize. The phosphorus rich compost being cheaper and eco-friendly and could be used as an alternative of chemical fertilizers (DAP and SSP) for improving crop productivity and sustainability of the system.

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Weed growth, yield and quality of summer cowpea [*Vigna unguiculata* (L.) Walp.] as influenced by weed management

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ABSTRACT

A field experiment was conducted in medium black soil at the College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during summer season of 2012 to study the effect of weed management practices on growth and yield of summer cowpea. Ten treatments *viz.*, pendimethalin 0.75 kg ha^{-1} as PPI, pendimethalin 0.75 kg ha^{-1} as PE, pendimethalin 0.90 kg ha^{-1} as PE, quizalofop 0.04 kg ha^{-1} as POE, fenoxaprop 0.075 kg ha^{-1} as POE, imazethapyr 0.075 kg ha^{-1} as POE, one H.W. at 30 DAS, two H.W. at 20 and 40 DAS, weed free and weedy check were conducted in randomized block design with four replications. Among herbicidal treatments, weed free recorded significantly lowest density weeds and dry weight of weeds, weed control efficiency, protein content, protein yield, seed yield, stover yield and biological yield, however, it remained at par with two H.W. at 20 and 40 DAS, quizalofop 0.04 kg ha^{-1} as POE, fenoxaprop 0.075 kg ha^{-1} as POE, imazethapyr 0.075 kg ha^{-1} as POE and H.W. at 30 DAS. The highest net returns of (₹ 32,008 ha^{-1}) was achieved from weed free treatment and remained on par with treatments *viz.*, quizalofop @ 0.04 Kg ha^{-1} as POE at 30 DAS, two H.W. at 20 and 40 DAS and fenoxaprop @ 0.075 Kg ha^{-1} as POE. Though, the maximum BCR (2.48) was gained with the quizalofop @ 0.04 Kg ha^{-1} as POE.

Key words: Cowpea, PPI, Quality, Yield

Cowpea commonly known as *lobia* is one of the important summer pulse crop grown for grain, forage and green manuring. The crop also checks the soil erosion in problematic areas and can later be ploughed down for green manure. It has considerable promise as an alternative pulse crop. Weed infestation is one of the important factors responsible for low yield of cowpea in India. The magnitude of losses largely depends upon the composition of weed flora, initial period of crop weed competition and intensity of weeds. Cowpea often suffers from severe weed competition especially during early growth stage resulting in yield reduction ranging from 20 to 70 per cent. An early growth stage (initial 30-40 DAS) of pulses is more critical (Singh *et al.* 2009). Weeds not only compete for nutrients, moisture, light and space but also increase the cost of cultivation and make the harvesting and threshing operations difficult. Crop yield losses due to weeds have been estimated 31.33% yield reduction. Therefore, it is indeed essential to control weeds effectively by any means during critical period of competition to exploit full yield potential of this crop. Hence, the present study was carried out to find out the effect of weed management practices on growth, yield and quality of summer cowpea.

MATERIALS AND METHODS

A field experiment was conducted during

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summer season of 2012 College of Agriculture, Junagadh Agricultural University, Junagadh in a randomized block design with four replications. The soil was medium black in texture, alkaline in reaction (pH 7.8), medium in organic carbon (0.57 %), low in available nitrogen (237.0 kg/ha), high in available phosphorus (32.5 kg P_2O_5/ha) and medium in potassium (269.0 kg K_2O/ha) content. The experiment consisted ten treatments *viz.*, pendimethalin 0.75 kg ha^{-1} as PPI, pendimethalin 0.75 kg ha^{-1} as PE, pendimethalin 0.90 kg ha-1 as PE, quizalofop 0.04 kg ha^{-1} as POE, fenoxaprop 0.075 kg ha^{-1} as POE, imazethapyr 0.075 kg ha^{-1} as POE, one H.W. at 30 DAS, two H.W. at 20 and 40 DAS, weed free and weedy check. The cowpea *cv.* 'GC-5' was sown on 28 February, 2012 using seed rate of 25 kg/ha with maintaining row to row 45 cm and plant to plant 15 cm distance. The crop was harvested on 22 May, 2012. The experimental plots were fertilized with nitrogen and phosphorus as per recommendation. The nitrogen (20 kg/ha) and phosphorus (40 kg/ha) were applied through DAP and urea, respectively and placed manually at 5-6 cm depth in the furrows before sowing. After establishment of plants, thinning was done along with gap filling at 15 days after sowing to maintain the plant to plant distance of 15 cm within rows in each plot. Seven irrigations (each of 5 cm depth) were given at different time of period as and when required by the crop. Observation on seed and stover yield, weed density and dry matter of weed were recorded at harvest.

RESULTS AND DISCUSSION

Effect on weed population

Data indicated that number of weeds *viz.*, grasses, broadweeds, dicot weeds and sedge ceporteal under weed free. The next best treatments two H.W. The hand weeding was the next best treatment followed at 20 and 40 DAS, quizalofop 0.04 kg ha^{-1} as POE, imazethapyr 0.075 kg ha^{-1} as POE, pendimethalin 0.75 kg ha^{-1} as PE, fenoxaprop 0.075 kg ha^{-1} as POE and One H.W at 30 DAS. This might be due to weed free condition maintained by hand weeding and interculturing as and when needed. These results indicated that pre-plant incorporation or pre-emergence application of pendimethalin controlled the weeds germination resulting in less no. of weeds. The removal of weeds at regular interval through hand weeding and inter-culturing accounted for nil grasses weeds under weed free. The application of post emergence herbicides *viz.*, quizalofop, imazethapyr and fenoxaprop reported less number of grasses as compared to unweeded check (Table 1). The lowest weed population was recorded with different manual & herbicidal treatment. The findings are in concurrence with those of Vivek *et al.* (2008) and Tomar (2011).

Dry weight of weeds

All the weed management treatments significantly reduced dry weight of weeds as compared to weedy check. Weed check having less dry weight and followed by two H.W. at 20 and 40 DAS, quizalofop 0.04 kg ha^{-1} as POE, One H.W at 30 DAS, imazethapy 0.075 kg ha^{-1} as POE and fenoxaprop 0.075 kg ha^{-1} as POE. This might be attributed to the effective control of weeds under these treatments, which reflected on less number of weeds and ultimately lower weed biomass (Table 1). In addition to this, dense crop canopy might have suppressed weed growth and ultimately less biomass accumulation. The unweeded check recorded significantly highest dry weight of weeds (1089.5 kg ha^{-1}). The findings are in conformity with those reported by Singh and Sohan (1996) and Kumar *et al.* (2008).

Weed indices

The lowest weed control efficiency and highest weed index were observed under W_{10} treatment. Thind *et al.* (1996) and Mathew and Sreenivasan (1998).

Effect on quality parameters

Protein content in grain (%) and protein yield (kg ha^{-1}) significantly influenced by different weed management treatment. Weed free check recorded maximum protein content (24.05 %) in grains and protein yield (323 Kg ha^{-1}). However, it remained at par with quizalofop 0.04 kg ha^{-1} as POE, two H.W. at 20 and 40 DAS, fenoxaprop

Table 1. Effect of different weed management treatments on density, dry weight, control efficiency and weed index in cowpea

Treatment	Weed population (No/m^2)			Dry wt. of weed (kg ha^{-1})	WCE (%)	WI (%)
	Grasses	Broadleaved	Sedge			
Pendimethalin 0.75 kg ha^{-1} as PPI	4.92 (24.32)	4.69 (22.43)	5.16 (27.00)	278.50	74.16	23.80
Pendimethalin 0.75 kg ha^{-1} as PE	4.84 (23.57)	4.03 (16.98)	5.18 (27.63)	298.25	72.57	24.75
Pendimethalin 0.90 kg ha^{-1} as PE	4.88 (23.93)	4.26 (18.38)	4.84 (23.75)	240.25	77.87	17.79
Quizalofop 0.04 kg ha^{-1} as POE	3.38 (11.50)	3.84 (15.03)	4.47 (20.25)	146.75	86.48	6.50
Fenoxaprop 0.075 kg ha^{-1} as POE	3.61 (13.15)	4.04 (16.68)	4.57 (21.25)	176.00	83.16	8.30
Imazethapyr 0.075 kg ha^{-1} as POE	3.47 (12.18)	3.74 (14.33)	4.40 (19.50)	168.00	84.39	15.00
One H.W. at 30 DAS	4.10 (17.03)	4.09 (17.38)	4.70 (23.13)	156.25	85.47	13.60
Two H.W. at 20 and 40 DAS	3.25 (10.87)	3.26 (10.80)	3.85 (15.14)	134.50	87.55	4.44
Weed free	0.00	0.00	0.00	0.00	100.00	0.00
Unweeded	5.93 (35.28)	5.34 (28.93)	5.62 (32.75)	1089.50	0.00	39.76
C.D. at 5%	0.66	1.08	NS	61.26	-	-

Figures in parenthesis are square root transformation ($\sqrt{x}$) values.

0.075 kg ha^{-1} as POE and imazethapyr 0.075 kg ha^{-1} as POE. While, minimum protein content (19.27 %) and protein yield (157 kg ha^{-1}) was recorded under unweeded check (Table 2). This can be ascribed to better control of weeds by manual weeding and herbicidal method as compared to unweeded condition, that might have increased uptake of nutrients and water, which in turn enhanced assimilation of amino acid leading to increased synthesis of protein. The lowest protein content under unweeded check can be ascribe to severe competition by weeds which might have resulted in less uptake of nutrients and water, which adversely affected the assimilation of amino acid and ultimately protein synthesis.

Effect on yield

Results revealed (Table 2) that weed free check produced highest grain, stover and biological yield, which were 66, 82 and 76 per cent higher over weedy check, respectively. Two H.W. at 20 and 40 DAS, quizalofop 0.04 kg ha^{-1} as POE and fenoxaprop 0.075 kg ha^{-1} as POE also produced grain, stover and biological yield statistically at par to that of 1342, 2233 and 3575 kg ha^{-1}, respectively. The yield attributes *viz.*, number of pods per plant, number of seeds per pod, length of pod (cm), seed weight per plant (g) recorded under this treatment due to less weed density and poor competition of weeds for crop growth. The methods which controlled the weeds, reduced the competition in terms of vegetative growth and nutrient uptake from the soil by weeds to a greater extent and thus helped faster growth of cowpea plants resulting in more number of pods per plant and better pod filling became more photosynthate available from source to sink. Remarkably the lowest grain, stover and biological yields of 808, 1228 and 2036 kg ha^{-1}, respectively was obtained by weedy check which might be due to strong competition of weeds for nutrients, moisture, sunlight etc. It is also indicated that weeds utilized resources

Table 2. Effect of different weed management treatments on protein content, protein yield, yield and economics of cowpea

Treatment	Protein content in seed (%)	Protein yield (kg ha^{-1})	Yield (kg ha^{-1})			Net Return (₹ ha^{-1})	B:C ratio
			Seed	Stover	Biological		
Pendimethalin 0.75 kg ha^{-1} as PPI	20.06	205	1019	1628	2647	21760	2.01
Pendimethalin 0.75 kg ha^{-1} as PE	19.78	200	1014	1600	2614	21518	2.00
Pendimethalin 0.90 kg ha^{-1} as PE	21.22	234	1100	1689	2789	24892	2.15
Quizalofop 0.04 kg ha^{-1} as POE	23.38	294	1256	2033	3289	31768	2.48
Fenoxaprop 0.075 kg ha^{-1} as POE	21.98	268	1222	1994	3217	30229	2.40
Imazethapyr 0.075 kg ha^{-1} as POE	22.22	252	1142	1928	3069	26795	2.23
One H.W. at 30 DAS	19.75	229	1153	1889	3042	27132	2.24
Two H.W. at 20 and 40 DAS	23.25	297	1275	2067	3342	31199	2.36
Weed free	24.05	323	1342	2233	3575	32008	2.28
Unweeded	19.27	157	808	1228	2036	14020	1.70
C.D. at 5%	2.61	51	192	286	317	-	-

more effectively than crop plants and suppressed the crop growth and thus resulted in poor growth and development of crop which tended to lower seed, stover and biological yield. These findings are corroborated the report of Singh and Prasad (1987) and Mishra and Bhanu Chandar (2006).

Economics

The economics of different treatments outlined in Table 2 indicated that weed free treatment observed remarkably higher net return with ₹ 32008 ha^{-1} and closely related treatment quizalofop 0.04 kg ha^{-1} as POE net return with ₹ 31768 ha^{-1} over weedy check, respectively. Though, the expenditure of weed free was maximum but seed and stover yields were more which tended to higher gross return and net return. The spraying of quizalofop 0.04 kg ha^{-1} as POE on cowpea crop was turn out the maximum B:C ratio (2.48). The highest seed and stover yield coupled with lower cost of production under these treatments were responsible for higher net returns. These findings are in close vicinity with those reported by Parasuraman (2000), Tiwari *et al.* (2007) and Tomar (2011).

CONCLUSION

On the basis of one year results obtained from present investigation, it can be concluded that effective weed management and profitable seed yield of cowpea in summer season can be obtained by keeping crop weed free throughout crop season or spraying of quizalofop 0.04 kg ha^{-1} as POE or carrying two H.W. at 20 and 40 DAS or spraying of fenoxaprop 0.075 kg ha^{-1} as POE depending upon the availability of labours under South Saurashtra agro climatic condition.

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Effect of vermicompost and biofertilizer on yield, quality and economics of cowpea

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ABSTRACT

A field experiment was conducted during *kharif* season of 2012 on loamy sand soil to study the effect of vermicompost and biofertilizers on growth, yield and quality of cowpea. The experiment consisted of four treatments of vermicompost (control, 2.0, 4.0 and 6.0 t ha^{-1}) and four treatment of biofertilizers (control, *Rhizobium*, PSB and *Rhizobium* + PSB) thereby making sixteen treatment combinations tested in randomized block design with four replications. Results indicated the application of vermicompost 4.0 t ha^{-1} maximum and significantly higher the net returns over other treatments and remained at par with 6.0 t ha^{-1} of vermicompost. However, seed, straw and biological yield, total root nodules and Leghaemoglobin content significantly increased upto 6.0 t ha^{-1} and remained at par with 4.0 t ha^{-1} of vermicompost over other treatments. But, application of vermicompost @ 6.0 t ha^{-1} significantly higher in case of protein content and effective root nodules over other treatments. The nitrogen fixation capacity unchanged under different levels of vermicompost. Results further indicated that seed inoculation with the *Rhizobium* + PSB significantly higher seed, straw and biological yield, protein content, total root nodules, effective root nodule, leghaemoglobin content, nitrogen capacity and net returns over control and other treatments.

Key words: Biofertilizer, Cowpea, Vermicompost, Yield

Cowpea [*Vigna unguiculata* (L.) Walp] commonly known as *lobia* is one of the important kharif pulse crop grown for grain, forage and green manuring in Rajasthan. The crop gives such a heavy vegetative growth and covers the ground so well that it checks the soil erosion in problem areas and can later be ploughed down for green manure. Gaur *et al.* (2004) reported that organic N is slowly mineralized and about 30 % N, 70 % P_2O_5 and 75 % K_2O is likely become available to the first crop and the rest of the nutrients to succeeding crops. Vermicompost has been advocated as good organic manure for use in the field crops. Vermicompost contain nutrients (1.67% N, 2.07% P and K 0.89 %) in the readily available form to the plants such as nitrate, exchangeable, soluble potassium, calcium and magnesium. It also contains biologically active substance such as plant growth regulators. Biofertilizer role assumes a special significance in present context of very high costs of chemical fertilizers. Use of biofertilizer can have a greater importance in increasing fertilizer use efficiency. Indian soils are poor to medium status in available nitrogen and available phosphorus. The seeds of pulses were inoculated with *Rhizobium* with an objective of increasing their number in the *rhizosphere* so that there is substantial increase in the microbiologically fixed nitrogen for the plant growth and development. Most of soils are poor in available phosphorus supply and low in organic matter. Seeds of pulses when inoculated with phosphate solubilizing bacteria they secret acidic substances which solubilize otherwise unavailable soil phosphorus. The inoculation with phosphate solubilizing bacteria, may be increase yield of crops by 10-30 per cent.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2012 at the Agronomy farm, S.K.N. College of Agriculture, Jobner (Rajasthan) in randomized block design with four replications. The soil was loamy sand in texture, alkaline in reaction (pH 8.2), low in organic carbon (0.23 %), available nitrogen (123.4 kg ha^{-1}), available phosphorus (15.8 kg P_2O_5 ha^{-1}) and medium in potassium (151.2 kg K_2O ha^{-1}) content. The experiment consisted of four levels of vermicompost (control, 2.0, 4.0 and 6.0 t ha^{-1}) and four treatments of biofertilizer (control, *Rhizobium*, PSB and *Rhizobium* + PSB) thereby, making sixteen treatment combinations. Recommend dose of fertilizer was 20 kg N and 40 kg P_2O_5 ha^{-1}. The cowpea cv. RC-19 was sown on 27th July, 2012 using seed rate 20 kg ha^{-1} with a row spacing of 30 cm. The crop was harvested on 1st October, 2012.

RESULTS AND DISCUSSION

Effect of vermicompost levels

The results indicated application of vermicompost 4.0 t ha^{-1} showed significantly higher net returns in cowpea as compared to other treatments and being at par with 6.0 t ha^{-1} of vermicompost. Application of vermicompost recorded the maximum and significantly higher net returns (₹ 39816 ha^{-1}) over other treatments (Table 1). The application of vermicompost 6.0 t ha^{-1} recorded significantly higher seed yield (14.25 q ha^{-1}), straw yield (24.75), biological yield (39.00 q ha^{-1}), total root nodules and leghaemoglobin content being at par with 4.0 t ha^{-1} of vermicompost. Progressive increase in vermicompost levels upto 6.0 t ha^{-1} significantly higher the protein content in seed and effective root nodules over the lower vermicompost levels (Table 1). The nitrogen fixation capacity unchanged under different levels of vermicompost. Legumes are known to have symbiotic association with *Rhizobium* bacteria which the application of vermicompost might have enhanced the population of desired microbes in the root zone during the early stage of infection by improving the physical, chemical and biological of properties of soil. Higher population of the desired organisms will always have greater possibilities of infection and consequently formation of more healthy and effective root nodules having higher amount of leghaemoglobin. These results are in agreement with finding of Sharma and Bhandari (2002) and Premi *et al.* (2004).

Table 1. Effect of vermicompost levels and biofertilizer on yield, quality and net returns of cowpea

Treatments	Yield (t ha^{-1})			Protein content (%)	Total root nodules	Effective root nodules	Leghaemoglobin content (mg per g)	Nitrogen fixation capacity (%)	Net returns (₹ ha^{-1})
	Seed	Straw	Biological						
Vermicompost levels									
V_0 : Control	0.88	1.58	2.47	21.39	12.65	9.43	1.25	9.96	28106
V_1 : 2.0 t ha^{-1}	1.15	2.04	3.19	23.11	13.90	10.75	1.47	10.10	35420
V_2 : 4.0 t ha^{-1}	1.36	2.37	3.73	24.05	15.35	12.12	1.72	10.15	39816
V_3 : 6.0 t ha^{-1}	1.43	2.48	3.90	24.62	16.56	13.30	1.90	10.16	38676
CD (P=0.05)	0.09	0.18	0.28	0.54	1.36	1.11	0.21	NS	4094
Biofertilizers									
No inoculation	1.05	1.86	2.91	21.56	12.86	8.90	1.28	-	28848
Rhizobium	1.22	2.13	3.35	23.75	15.10	12.05	1.55	13.70	35956
PSB	1.19	2.10	3.29	23.42	13.90	11.10	1.51	12.26	34994
Rhizobium + PSB	1.37	2.38	3.74	24.44	16.60	13.55	1.99	14.41	42220
CD (P=0.05)	0.09	0.18	0.28	0.54	1.36	1.11	0.21	0.34	4094

Effect of biofertilizers

The progressive increase in biofertilizer as seed inoculation with *Rhizobium* + PSB significantly higher the seed yield, straw yield, biological yield, protein content in seed, total root nodules, effective root nodules, leghaemoglobin, nitrogen fixation capacity and net returns over control, *Rhizobium* and PSB (Table 1). Seed inoculation with *Rhizobium* + PSB recorded the maximum and significantly higher net returns (₹ 42220 ha^{-1}) over other treatments. The increase in net returns might be due to higher seed yield (13.7 q ha^{-1}) and straw yield (23.8 q ha^{-1}) obtained under this treatment as compared to cost involved under this treatment. The combined inoculation of *Rhizobium* and PSB has proved one of the most efficient inoculations in increasing total and effective number of root nodules per plant, leghaemoglobin content in root nodules and nitrogen fixation capacity (Chattopadhyay and Dutta, 2003 and Mukherjee and Sarkar, 2007). The increased nodulation under seed inoculation of *Rhizobium* + PSB might be due to close association of both the microbial population and their activities resulting in substantially more nodulation as compared to *Rhizobium* and PSB alone. Similar results have been reported by Bansal (2009) in greengram and Rana *et al.* (2006), in rajmesh.

CONCLUSION

Based on the results of the experiment, it could be concluded that the application of vermicompost 4.0 t/ha and combined seed inoculation with *Rhizobium* + PSB significantly increased seed yield, straw yield, biological yield, protein content in seed and symbiotic efficiency and higher net returns was found in this treatment over other treatments.

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Phenology and productivity of mustard (*Brassica juncea* L.) under varying sowing environment and irrigation levels

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Abstract

A field experiment was conducted at Rajasthan College of Agriculture, Udaipur (Rajasthan) during *rabi* seasons of 2008-09 and 2009-10 to study the effect of thermal regimes on phenology and productivity of mustard *(Brassica juncea)* variety Bio-902. The experiment consisted of four dates of sowing (5th October, 20th October, 4th November and 19th November) and four irrigation levels (no irrigation, at vegetative stage, at vegetative and flowering stages and at vegetative, flowering and siliquae development stages). The experiment was laid out in split plot design having four replications. Regression models were developed to predict the seed yield of mustard. The crop sown on 5th October and 20th October gave the maximum seed yield (17.01q ha^{-1}) and significantly higher harvest index over 4th November and 19th November sown crops. Seed yield of mustard have positive correlation with maximum and minimum temperatures up to 75 DAS, thereafter, negative correlation was observed from 90 DAS to maturity. An increase of 1.0°C mean temperature during 90 to 105 DAS caused reduction in seed yield by 4.0 q ha^{-1}. The mean temperatures of 21.0 to 25.5°C and 18.7 to 20.5°C during vegetative and reproductive phase, respectively, was found conducive for higher productivity in mustard. Number of days for reproductive phase, growing degree days (GDD) and helio thermal unit (HTU) decreased with the successive delay in sowing. Late sown crop exhibited higher canopy temperature at 75 and 90 DAS. Application of three irrigations gave significantly higher seed yield by 92.0, 28.0 and 4.0 per cent over no irrigation, one and two irrigations, respectively.

Key words: Mustard, temperature, irrigation level, growing degree days, helio thermal unit, seed yield

India occupies premier position in global oilseed scenario, accounting for about 23.5 per cent area and 17.6 per cent of production (FAO, Year book, 2010). India is the third largest oilseed economy in the world. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6 per cent in the total oilseeds production and ranks second after groundnut and sharing 27.8 per cent in the India's oilseed economy. Oilseed constitutes the second largest agricultural commodity after cereals in India, producing 11.94 MT from 22.9 mha area with the average productivity of 955 kg ha^{-1}. Rapeseed-Mustard accounts for 22.7% area and 25.9% production in total oil seed area and production in India. The average productivity, area and productivity under repeseed and mustard was 5.5 mha, 6.4 MT and 1159 kg ha^{-1}. (Economic Survey, 2011). Mustard is a winter season crop and its physiological and morphological developments are markedly influenced by weather conditions. Among various weather parameters, temperature is considered as prime weather element that affect crop growth and development.

Hall (1992) reported that flowering is the most sensitive stage for temperature stress, probably due to vulnerability for pollen development, anthesis and fertilization. High temperature in mustard causes flower abortion with appreciable loss in seed yield (Rao *et al.*, 1992). Therefore, the present experiment was undertaken to study the effect of thermal regimes on phenology and productivity of Indian mustard variety Bio-902.

MATERIALS AND METHODS

The field experiment was conducted during two consecutive *rabi* seasons of 2008-09 and 2009-10 at Instructional Farm, Rajasthan College of Agriculture, Udaipur situated at Southern part of Rajasthan at 24°34' N latitude and 73°42' E longitude and an altitude of 582.0 m above mean sea level. The Instructional Farm falls under agro-climatic zone IV A "Sub-humid Southern Plain and Aravalli Hills" of Rajasthan and agro climatic zone VIII (Central plateau and hills) of India. The soils of experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.9) and calcareous in nature. The experiment was laid out in split plot design with four replications. The experiment consisted of four dates of sowings (5th October, 20th October, 4th November and 19th November) assigned in main plots and four irrigation levels [no irrigation (I_0), one at vegetative stage (I_1), two at vegetative and flowering stages (I_2), and three at vegetative, flowering and siliquae development stages (I_4)] in sub plot treatments. In each irrigation treatment applies 50 mm depth water. Irrigation depth was measured by Parshall flume. Sowing was done manually followed by irrigation for proper germination. Mustard variety Bio-902 was sown on the stipulated dates as per treatments with a seed rate of 5 kg ha^{-1} at 30 cm x 10 cm spacing followed by irrigation. The crop was fertilized with 60 kg N and 40 kg P_2O_5 ha^{-1}. The temperature data during the crop season were recorded from Meteorological observatory of Instructional Farm, Rajasthan College of Agriculture, Udaipur. The growing degree-days were computed by following formula:

Accumulated GDD = $\Sigma\,(T_{mean} - T_{base})$

Where,

T_{mean} = (Maximum temperature + Minimum temperature)/2

T_{base} = Base temperature of mustard crop (5°C) as suggested by Rao, 2008

Irrigation water productivity was calculated as suggested by Chandra (2015)

Irrigation water productivity (kg/ha – cm) = Yield/total irrigation water depth

RESULTS AND DISCUSSION

Effect of temperature on yield

Mean seed yield of mustard showed negative relationship with the mean temperature experienced between 90 to 105 days after sowing

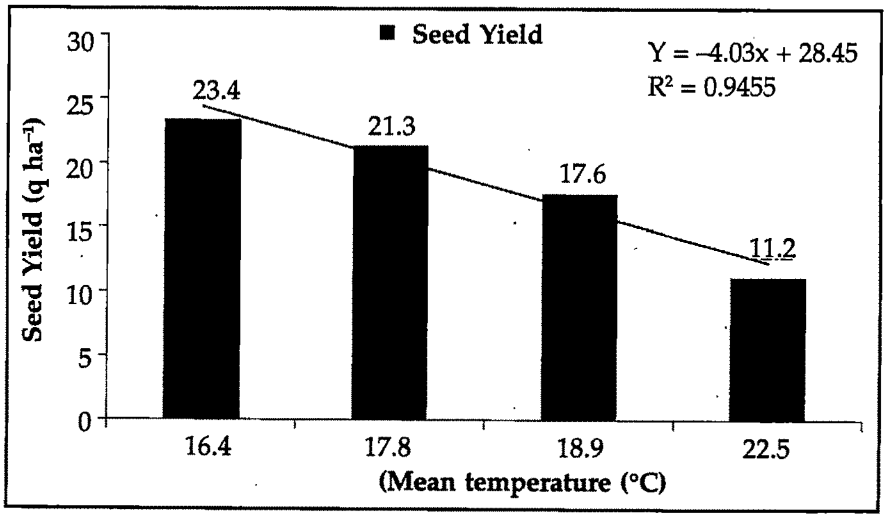

Fig. 1. Relationship between mean temperature (90-105 DAS) and seed yield of mustard under three irrigation (mean of 2008-09 and 2009-10)

(Fig. 1). An increase of 6.1°C temperature between 90 to 105 DAS resulted in decline of seed yield of mustard by 12.20 qha^{-1} under assured irrigation. Two years mean data revealed that the highest seed yield of 23.4 qha^{-1} was obtained under 5th October sown crop when the mean temperature was 16.4°C during 90-105 days of crop growth. While the lowest seed yield of 11.2 qha^{-1} was recorded under 19th November sown crop when the mean temperature was 22.5°C during 90-105 days. Data (Table-1) also shows higher mean temperature 90 DAS onwards under 4th November and 19th November sown crops. High temperature stress directly or indirectly affects plant photosynthetic functions by changing the structural organization and physiochemical properties of thylakoid membranes. The rate of photorespiration increase with increasing temperature which reduces net photosynthesis and probably the seed yield of the crop (Hayat *et al.* 2009). According to Angadi *et al.* (2000) in *Brassica* species, a temperature of 35/15°C for 1 week during early flowering reduces seed yield drastically. Rao *et al.* (2011) has also reported that increase in temperature decrease seed yield of mustard.

Days taken to attain various phenophases of mustard

Data pertaining to days taken for vegetative and reproductive phase as influenced by different weather environments are presented in Table 3. Data show that vegetative phase of mustard was extended by 4 to 5 days in delayed sowing (4th November & 19th November) as compared to timely sown crop (5th October). However, reproductive phase of the crop was shortened by 8 to 10 days with delayed sowing (from 76 days to 66 days). Early sown crop took 114 days for maturity.

With regard to irrigation levels, the number of days required to attain maturity were increased with increasing levels of irrigation in all sowing dates. The reproductive phase was increased by 2 and 4 days with the application of two and three irrigations over no irrigation.

Table 1. Mean temperature experienced during the crop season (Mean of two years)

Sowing date	1-15 DAS	16-30 DAS	31-45 DAS	46-60 DAS	61-75 DAS	76-90 DAS	91-105 DAS	106 to maturity
5th October	26.4	23.9	22.1	19.2	20.7	18.0	16.4	19.8
20th October	24.0	22.5	19.5	20.7	18.4	16.8	17.8	19.0
4th November	21.8	19.3	20.6	18.1	16.2	18.7	19.0	21.1
19th November	19.3	20.6	18.1	16.2	18.7	19.0	22.5	24.6

Table 2. Days taken to attain different phenophases of mustard under varying weather environment and irrigation levels (2008-09 and 2009-10)

Treatment	Phenophases	I_0	I_1	I_2	I_3	Mean
5th October	Vegetative	37	38	39	39	38
	Reproductive	73	73	77	82	76
	Total	110	111	116	121	114
20th October	Vegetative	38	39	39	40	39
	Reproductive	71	72	76	79	74
	Total	109	110	115	118	113
4th November	Vegetative	42	43	43	43	42
	Reproductive	66	66	68	72	68
	Total	108	109	110	115	110
19th November	Vegetative	41	43	44	45	43
	Reproductive	65	65	67	69	66
	Total	106	108	110	114	109
Mean	Vegetative	40	41	41	42	41
	Reproductive	69	69	72	76	71
	Total	108	110	113	117	112

Table 3. Accumulated GDD (°C day) required to attain different phenophases of mustard (Mean of 2 years)

Treatment	Phenophases	I_0	I_1	I_2	I_3	Mean
5th October	Vegetative	731	749	756	765	750
	Reproductive	1000	998	1061	1120	1045
	Total	1731	1747	1817	1885	1795
20th October	Vegetative	642	658	664	671	659
	Reproductive	957	963	1022	1063	1001
	Total	1599	1621	1686	1734	1660
4th November	Vegetative	650	666	666	673	663
	Reproductive	863	863	888	955	892
	Total	1513	1529	1554	1628	1556
19th November	Vegetative	608	623	623	633	621
	Reproductive	903	924	968	1033	957
	Total	1510	1546	1591	1666	1578
Mean	Vegetative	658	674	677	686	673
	Reproductive	931	937	985	1043	974
	Total	1589	1611	1662	1729	1647

Similarly, total crop duration also increased by 2, 5 and 9 days with application of one, two and three irrigations, respectively over no irrigation.

Growing degree days (GDD)

Data with respect to GDD required for vegetative and reproductive phase of the crop in Table 4 show that GDD required for vegetative phase were less as compared to that required for reproductive phase in all sowing dates (Table 4). The highest GDD of 1885°C days were required for maturity under 5th October sown crop with three irrigations. Total GDD required for maturity was decreased with delayed sowing. Among the different irrigation levels, it was noted that the lowest GDD of 1589°C days were required under no irrigation. The GDD requirement increased from 1589 to 1729°C days with the increasing level of irrigation from no irrigation to three irrigations. Kaur and Hundal (2006) in *Brassica* species under Punjab condition reported that accumulated GDD required for maturity decreased with delayed sowing.

Helio Thermal Units (HTU)

Data pertaining to helio thermal units (HTU) in Table 5 show that reproductive phase of the

Table 4. Helio Thermal Unit (°C day hours) required to attain different phenophases of mustard (Mean of 2 years)

Treatment	Phenophases	I_0	I_1	I_2	I_3	Mean
5th October	Vegetative	6195	6312	6314	6378	6300
	Reproductive	6909	6845	7379	7864	7249
	Total	13104	13157	13692	14242	13549
20th October	Vegetative	5296	5431	5494	5554	5444
	Reproductive	6827	6881	7282	7621	7153
	Total	12123	12312	12776	13175	12596
4th November	Vegetative	4871	4979	4978	5018	4961
	Reproductive	6300	6333	6544	7153	6582
	Total	11171	11312	11522	12170	11544
19th November	Vegetative	4404	4521	4521	4607	4513
	Reproductive	7140	7316	7721	8305	7620
	Total	11544	11836	12242	12912	12133
Mean	Vegetative	5192	5311	5327	5389	5304
	Reproductive	6795	6844	7231	7736	7151
	Total	11987	12154	12558	13125	12456

Table 5. Effect of different sowing environment and irrigation levels on seed yield and harvest index of mustard (2008-09 & 2009-10)

Treatments	Seed yield (qha^{-1})			Harvest Index (%)			Irrigation water productivity (kg/ha-cm) Pooled basis
	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled	
Sowing dates							
5th October	15.37	18.65	17.01	29.13	30.21	29.67	149.10
20th October	15.59	18.42	17.01	28.77	30.24	29.51	150.27
4th November	14.2	12.80	13.50	26.99	27.21	27.10	122.66
19th November	9.66	9.95	9.81	24.53	24.82	24.68	95.90
CD (P=0.05)	1.325	1.460	1.272	1.29	1.383	1.393	8.540
Irrigation levels							
I_0	9.11	9.54	9.33	23.34	23.96	23.65	-
I_1	10.86	14.35	12.61	26.38	27.52	26.95	126.09
I_2	16.46	17.57	17.02	29.69	30.96	30.33	113.44
I_3	18.37	18.36	18.37	30.01	30.05	30.03	91.82
CD (P=0.05)	1.203	0.838	1.106	1.29	0.987	1.141	8.540

crop required more helio thermal units than vegetative phase in all the sowing dates. Delayed sowing caused reduction in helio thermal units requirement for vegetative as well as reproductive phase. The maximum HTU of 13549°C day hours was recorded under 5th October sown crop. With respect to irrigation levels, it was noted that HTU for maturity of the crop was increased with each successive increase in number of irrigations. Application of one, two and three irrigations resulted into 167, 571 and 1138°C day hours more HTU over no irrigation, respectively.

Seed yield and harvest index

Pooled data of 2 years, show that 5th October and 20th October sown crop gave the maximum seed yield (17.01 qha^{-1}) which was significantly superior over 4th November and 19th November sown crop (Table 5). The crop sown on 4th November and 19th November resulted in the reduction in seed yield by 21.0 and 42.0%, respectively over 5th and 20th October sown crop. High temperature negatively affected plant growth and survival and hence crop yield (Boyer, 1982). Similar result was also reported by Kaur and Hundal (2006) in *Brassica* species under Punjab conditions, while maximum harvest index 29.67 % was recorded under 5th October sown crop, which was at par with 20th October sown crop. The crop sown on 4th November and 19th November gave 9.0 and 17.0 % lower harvest index as compared to 5th October sown crop. Angadi *et al.* (2000) also concluded that high temperatures of 35/15°C reduced harvest index significantly. A significant increase in harvest index was observed up to application of two irrigations. Application of two irrigations gave too high higher harvest index over no irrigation and one irrigation, respectively. The crop sown on 20th October gave the maximum irrigation water productivity (150.27 kg/ha-cm) which was significantly higher over 4th November and 19th November sown crops but at par with 5th October sown crop. Irrigation water productivity was highest 186.57 (kg/ha-cm) in no irrigation and it decreased with successive increase in number of irrigations.

Data in Table 6 show that seed yield of mustard has positive correlation with maximum and minimum temperatures up to 75 DAS. However, from 90 DAS to maturity, seed yield has negative correlation with maximum and minimum temperatures which is also supported by Rao *et al.* (2011).

Table 6. Correlation coefficient between seed yield and temperatures at different growth stages of mustard

Temperature	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	106 to maturity
Maximum Temp.	0.651	0.597	0.631	0.685	0.055	-0.603	-0.628	-0.683
Minimum Temp.	0.543	0.504	0.415	0.566	0.459	-0.556	-0.689	-0.652
Mean Temperature	0.656	0.629	0.542	0.655	0.291	-0.646	-0.670	-0.678

CONCLUSION

An increase of 1.0°C mean temperature during 90 to 105 days after sowing caused reduction in seed yield of mustard by 4.0 q/ha. The highest growing degree days of 1885°C day and helio thermal units of 14242°C day hours was required for attaining maturity under early sown crop (5th October) with three irrigations. Mustard sowing from 5th October to 20th October is conducive for getting higher seed yield.

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Impact of biofertilizer and irrigation in enhancing productivity potential of linseed (*Linum usitatissimum* L.) under *utera* condition

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ABSTRACT

A field experiment was conducted during *rabi* 2012-13 and 2013-14 at Agricultural Research Institute, Patna, Bihar to study the effect of biofertilizer *viz.*, Phosphate Solubilising Bacteria, Azotobacter and irrigation in enhancing productivity potential of linseed (*Linum usitatissimum* L.) under *utera* condition. *Utera* linseed responded significantly to the irrigation treatments with highest yield recorded under two irrigations, where as the percentage increase in yield was found higher for one irrigation over no irrigation. All the fertility treatments showed significant increase in seed yield with respect to control during both the years. The treatment, 100% recommended dose of nitrogen and seed inoculation with PSB and Azotobacter significantly out yielded other treatments during both the year of experimentation. The interaction effect also revealed significant increase in seed yield with respect to irrigation and fertility, with highest yield of 1074 kg/ha and 844 kg/ha recorded under two irrigations along with application of 100% RDN + PSB and Azotobacter during 2012-13 and 2013-14 respectively. The percentage increase in yield by 100% RDN + PSB and Azotobacter, over the control fertility treatments, was found higher when applied with one irrigation with values of 132% and 113% during 2012-13 and 2013-14 respectively. The highest net return and B:C ratio was recorded for two irrigations with 100% RDN + PSB and Azotobacter, followed by one irrigation with 100% RDN + PSB and Azotobacter.

Key words: PSB, Azotobacter, Irrigation, Utera, Linseed

Utera cropping, also known as relay cropping, plays an important role in intensifying the rice fallows in rainfed and partially irrigated areas. India accounts for 79% (11.65 million ha) of the total rice fallows of South Asia (15.0 million ha) (Subbarao *et al.* 2001). The rice fallows offer good scope for area expansion of the short duration oilseeds, pulse crops and crop intensification. Development and popularization of improved agro-technology will boost production, thus can enhance income and livelihood security of farming community in these areas. These rice fallows have various constraints for cop production due to different abiotic factors. These conditions provide scope for *utera* cropping by utilising the residual moisture of the previous paddy crop. Generally *utera* crop offers less scope for application of manures or fertilizers due to no-tillage practice as it is grown by broadcasting in the standing paddy crops. Consequently, nutrient mobilization is reduced, leading to nutrient stress to crops. Application of biofertilizers and foliar nutrients offers great scope for research under such condition, playing vital role in maintaining long term soil fertility and sustainability, by fixing atmospheric nitrogen, mobilizing fixed macro and micro nutrients and converting insoluble phosphorus in the soil into forms available to plants, thereby increasing their efficiency and availability (Sheraz Mahdi *et al.* 2010). Moisture stress is also a major impediment under such condition limiting the yield potentiality of the crop through its impact on plant growth, development, nutrient mobilization and uptake. Linseed (*Linum usitatissimum* L.), a crop with rich source of omega-3 fatty acid, offers great scope under *utera* cropping system. But its genetic yield potentiality is reduced under nutrient and moisture stress conditions. Therefore, a study was undertaken to study the effect of bio-fertilisers *viz.*, Phosphate Solubilising Bacteria (PSB), Nitrogen Fixing Bacteria like Azotobacter and irrigation in enhancing the productivity potential of linseed under *utera* condition.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* seasons of 2012-13 and 2013-14 to study the effect of bio-fertilisers *viz.*, PSB, Azotobacter and irrigation in improving productivity potential of linseed under *utera* condition at Agricultural Research Institute, Lohiya Nagar, Patna of Bihar Agricultural University, Sabour, Bihar on a medium land situation. The place is situated at 25°30'N latitude, 85°15'E longitude and an elevation of 57.8 m above mean sea level. The soil was vertisol having clayee texture, 7.2 pH, 0.36% organic carbon, 20.5 kg/ha available P_2O_5 and 190 kg/ha available K_2O. The total rainfall during the cropping period was 26.4mm and 55.6mm in first and second years of experimentation respectively.

The experiment was laid out in a split plot design with three levels of irrigation in main-plot and four levels of fertility in sub-plot, replicated thrice. The main-plot treatments comprised of no irrigation, one irrigation (at 55 days after sowing) and two irrigations (first at 30 days after paddy harvest and second at 30 days after 1st irrigation). The subplots include four levels of fertility viz., no fertiliser (control), 100% recommended dose of nitrogen (RDN) as basal, 100% RDN as basal + seed inoculation with PSB and Azotobacter and 100% RDN as basal + foliar spray of 2% urea solution at pre-flowering stage of linseed, by taking 30:0:0 as the recommended dose of $N:P_2O_5:K_2O$ respectively. The biofertilizers like PSB and Azotobacter were applied by inoculating the seeds @ 500g. each /hectare. Seeds of linseed *cv.* Shekhar were broadcasted @ 50 kg/ha over the standing rice crop (15 days before harvesting of rice) during 2nd week of November and harvested during 4th week of March.

Observations on yield attributes like plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, test weight and seed yield were recorded, treatment wise, at maturity in both the years. The economics was worked out considering the prevailing market price of inputs and outputs in the respective years of study. The data were statistically analysed applying the techniques of analysis of variance and the significance of different sources of variations were tested by error mean square of Fisher Snedecor's 'F' test at probability level 0.05 (Cochran and Cox 1977).

RESULTS AND DISCUSSION

Effect of treatments on different components of utera linseed

Plant height

Significant difference in plant height was recorded between different irrigation treatments, with highest plant height recorded for two irrigations, which was found at par with one irrigation, but differ significantly with no irrigation during both the years of experimentation (Table 1). Fertility treatments also showed significant difference in plant height with highest plant height recorded for 100% RDN as basal + seed inoculation with PSB and Azotobacter, which might be due to the effect of PSB and Azotobacter in supplying additional N and P_2O_5 to the crop.

Number of primary branches per plant

The number of primary branches per plant increased significantly with respect to irrigation treatments, with highest number recorded for two irrigations which did not differ significantly with one irrigation during both the years of experimentations. Similar type of significant increase in yield attributes due to irrigation was earlier reported by Gabiana (2005).

Significant difference in the number of primary branches per plant was also recorded for fertility treatments with highest number recorded

Table 1. Yield components and yield of *utera* linseed as influenced by irrigation and fertility levels

Treatments	2012-13						2013-14					
	Plant height (cm)	Branches/ plant	Capsule/ plant	Seeds/ capsule	Test weight (g)	Seed yield (kg/ha)	Plant height (cm)	Branche/ plant	Capsules/ plant	Seeds/ capsule	Test weight (g)	Seed yield (kg/ha)
Irrigation levels												
No Irrigation	42.4	1.9	12.9	7.5	6.73	536	42.9	1.6	15.5	7.6	5.72	427
One Irrigation	44.7	2.3	16.0	7.7	6.66	729	46.2	1.9	18.6	7.8	5.83	580
Two Irrigations	47.0	2.4	17.5	8.0	6.93	852	47.8	2.1	21.0	8.0	5.96	678
SEm (±)	0.83	0.08	0.63	0.20	0.19	20.3	0.86	0.08	0.74	0.19	0.09	16.7
CD (p=0.05)	3.26	0.33	2.50	NS	NS	79.8	3.39	0.33	2.92	NS	NS	65.8
Fertility levels												
No fertiliser (Control)	40.3	1.9	10.3	7.1	6.54	419	41.3	1.9	13.5	7.3	5.70	365
100% RDN	45.6	2.2	15.6	7.8	6.69	719	46.3	2.2	17.6	7.9	5.78	575
100% RDN + PSB & Azotobacter	47.2	2.5	19.6	8.1	6.87	898	48.6	2.6	22.9	8.1	5.99	715
100% RDN + 2% Urea	46.0	2.3	16.5	7.8	6.98	787	46.3	2.3	19.4	7.9	5.88	592
SEm (±)	0.46	0.08	0.60	0.21	0.20	19.8	0.54	0.10	0.60	0.20	0.08	13.1
CD (p=0.05)	1.36	0.24	1.77	0.62	NS	58.5	1.62	0.28	1.78	0.59	NS	38.9

NS: Non significant

for 100% RDN as basal + seed inoculation with PSB and Azotobacter. But the treatment, 100% RDN + foliar spray of 2% urea solution at pre-flowering was found at par with 100% RDN as basal, during both the years.

Capsules per plant

Application of irrigation fetched significantly higher number of capsules per plant, with highest number *viz.*, 17.5 and 21.0, recorded for two irrigations in 2012-13 and 2013-14 respectively, which was found at par with one irrigation. Similar type of response of capsules per plant of linseed to irrigation was earlier reported by Husain *et al.* (2000). But the percentage increase was found higher for one irrigation *i.e.*, 24% and 20% with respect to no irrigation, during 2012-13 and 2013-14 respectively.

The fertility treatments showed significant increase in the number of capsules per plant, with highest value *viz.*, 19.6 and 22.9 recorded for 100% RDN as basal + seed inoculation with PSB and Azotobacter during 2012-13 and 2013-14 respectively. The effect might be due to the activity of N- fixers, playing a major role in improving soil fertility and yield attributing characters as reported by Subashini *et al.* (2007), Kachroo and Razdan (2006) and Son *et al.* (2007). The lowest number of capsules per plant was recorded for control fertility during both the years.

Seeds per capsule and Test weight

No significant difference in the number of seeds per capsule was recorded for irrigation treatments, where as the fertility treatments show significant variation with the highest number of seeds per capsule (8.1) recorded for 100% RDN + PSB and Azotobacter during both the years. It is well known that phosphorous solubilizing bacteria can increase the available phosphorous in the soil which can enhance the number of seeds in plant (Tohidi-Moghaddam *et al.* 2004). The interaction effect shows that at the same level of irrigation, the highest seeds per capsule (8.4) recorded for two irrigations, fertilized with 100% RDN + PSB and Azotobacter during both the years and the lowest value *viz.*, 6.7 and 7.0, obtained with no irrigation and control fertility, during 1st and 2nd years respectively.

With respect to test weight, no significant difference was recorded for both irrigation and fertility treatments. However, 100% RDN + foliar spray of 2% urea solution at pre-flowering fetched highest test weight (6.98 g) during 2012-13, whereas during 2013-14 the highest value (5.99 g) was recorded under 100% RDN + PSB and Azotobacter.

Seed yield

Utera linseed responded significantly to the irrigation treatments with highest seed yield of 852 kg/ha and 678 kg/ha recorded under two irrigations in 2012-13 and 2013-14 respectively, which differed significantly with one irrigation. During both the years, the per centage increase in yield was found higher for one irrigation, over no irrigation, with values of 59% and 36% during 2012-13 and 2013-14 respectively, compared to two irrigations over one irrigation,.

The higher response of yield to one irrigation applied at 55 days after sowing might be due to the fact that one irrigation fulfilled the minimum water requirement of the crop at the critical stages and helped in better uptake of nutrients, there by promoting significant growth and development. The results are in conformity with the recommendation of Vittal *et al.* (2005).

The fertility treatments showed significant increase in seed yield with respect to no fertility. The treatment, 100% RDN + PSB and *Azotobacter*, significantly out yielded other treatments during both the years, with the yields of 898 kg/ha and 715 kg/ha during 1st and 2nd year of experimentations respectively. The result is in conformity with those of Pramanik and Bera (2013) on sunflower. The treatment, 100% RDN + foliar spray of 2% urea solution at pre-flowering, was significantly superior to 100% RDN during 2012-13, whereas during 2013-14, both the treatments recorded at par yields.

The interaction effect revealed significant increase in seed yield with respect to irrigation and fertility, with highest yield of 1074 kg/ha and 844 kg/ha recorded under two irrigations with 100% RDN + PSB and *Azotobacter* during 2012-13 and 2013-14 respectively (Table 2). The lowest seed yield was recorded under no irrigation with zero fertility, during both the years. The treatment, 100% RDN + PSB and Azotobacter, increased the yield by 93%, 132% and 114% over the no fertility treatments of zero, one and two irrigations respectively in 2012-13, where as in 2013-14, the treatment 100% RDN + PSB and Azotobacter increased the seed yield by 87%, 113% and 89% than the control fertility treatment of zero, one and two irrigations respectively. This might be due to the activity of N-fixing and phosphate solubilizing bacteria, in supplying additional N and P_2O_5 to the crop in comparison to other fertility treatments.

Table 2. Seed yield of *utera* linseed as influenced by interaction effect of irrigation and fertility

	2012-13				2013-14			
	Control (F_0)	100% RDN (F_1)	100% RDN + PSB & *Azotobacter* (F_2)	100% RDN + 2% urea (F_3)	Control (F_0)	100% RDN (F_1)	100% RDN + PSB & *Azotobacter* (F_2)	100% RDN + 2% urea (F_3)
No irrigation (I_0)	354	505	686	600	308	407	576	416
One irrigation (I_1)	401	767	934	812	341	609	726	646
Two irrigations (I_2)	502	885	1074	949	447	708	844	714
	I × F		F × I		I × F		F × I	
SEm (±)	34.1		35.8		22.7		25.8	
CD (p=0.05)	101.3		117.5		67.4		87.1	

I × F : Comparison of fertility treatments at the same level of irrigation,
F × I : Comparison of irrigation treatments at the same level of fertility

Table 3. Economics of *utera* linseed as influenced by irrigation and fertility

Treatments		2012-13					2013-14				
		Seed yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	NMR (Rs./ha)	B:C ratio	Seed yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	NMR (Rs./ha)	B:C ratio
I_0	F_0	354	9632	11328	1696	1.18	308	10571	12320	1749	1.17
	F_1	505	10002	16160	6158	1.62	407	10961	16280	5319	1.49
	F_2	686	10202	21952	11750	2.15	576	11161	23040	11879	2.06
	F_3	600	10059	19200	9141	1.91	416	11021	16640	5619	1.51
I_1	F_0	401	10526	12832	2306	1.22	341	11478	13640	2162	1.19
	F_1	767	10896	24544	13648	2.25	609	11868	24360	12492	2.05
	F_2	934	11096	29888	18792	2.69	726	12068	29040	16972	2.41
	F_3	812	10953	25984	15031	2.37	646	11928	25840	13912	2.17
I_2	F_0	502	11420	16064	4644	1.41	447	12385	17880	5495	1.44
	F_1	885	11790	28320	16530	2.40	708	12775	28320	15545	2.22
	F_2	1074	11990	34368	22378	2.87	844	12975	33760	20785	2.60
	F_3	949	11847	30368	18521	2.56	714	12835	28560	15725	2.23

I_0: No irrigation, I_1: One irrigation, I_2: Two irrigations, F_0: No fertiliser, F_1: 100% RDN as basal, F_2: 100% RDN + PSB & *Azotobacter*, F_3: 100% RDN + foliar spray of 2% urea solution at pre-flowering, I × F: Comparison of fertility treatments at the same level of irrigation, F × I: Comparison of irrigation treatments at the same level of fertility.

Economics

From the economics point of view, the interaction effect showed that the highest net return and B:C ratio of Rs. 22378 and 2.87, respectively, were recorded for two irrigations with 100% RDN + PSB and *Azotobacter* which was followed by one irrigation with 100% RDN + PSB and Azotobacter, with net return and B:C ratio of Rs.18792 and 2.69 respectively, for 2012-13. Similar trend of net return and B:C ratio with values Rs. 20785 and 2.60 respectively, were recorded for two irrigations with 100% RDN + PSB and Azotobacter, followed by one irrigation with 100% RDN + PSB and Azotobacter, with respective values of Rs.16972 and B:C ratio 2.41 for 2013-14 (Table 3).

CONCLUSION

The study suggested that there was very high response of irrigation towards enhancing the yield components and seed yield of *utera* linseed. Two irrigations increased substantially the yield and net return of *utera* linseed, where as one irrigation had also significant effect in increasing the productivity potential of the crop. It can also be concluded that bio-fertilizers like PSB and Azotobacter, when inoculated with seeds, in addition to the basal application of nitrogen, commanded significant response in *utera* linseed by increasing seed yield and net return substantially.

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On-farm evaluation and adoption of improved sweet potato *(Ipomoea batatas)* cultivation among tribal farmers in Koraput region of Odisha, India

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Abstract

A study was conducted at Krishi Vigyan Kendra, Semiliguda in Koraput district of Odisha from 2010-2014 to evaluate the performance of sweet potato varieties *Kishan* and *ST-14* on farmers' field. Front line demonstrations (FLD) were conducted with scientific package of sweet potato cultivation under rainfed conditions. The increase in yield under demonstrations was in the range from 44-57% for the varieties *Kishan* and 19-23% in *ST-14*, respectively over local cultivars. An extension gap ranging from 56-68 q/ha and 23-28 q/ha in yield was perceived between FLD and Farmers' Practice (FP) throughout years for variety *Kishan* and *ST-14*, respectively. The average technology gap of total 60 FLD's for tested varieties was 74 and 53 q/ha for *Kishan* and *ST-14*, respectively; which is 32 and 40% of variety's potential yield. Mean values of three years incites that *Kishan* variety noted more net returns (₹ 37,496) in comparison to *ST-14* (₹ 30,070). Adoption data signposts that recommended practices like adoption of HYV's, vine cuttings preparation, nutrient management and pest management were adopted by the respondents mediocrely; with adoption quotient of 69.4, 60.0, 69.2 and 63.3, respectively. The study concludes that with a meager incremental increase in cost of cultivation (₹ 1563-2000/ha) small and marginal farmers can fetch higher net profits of ₹ 30, 000 -35,000/ha.

Key words: Sweet potato, Front line demonstration, Extension gap, Technology gap.

Sweet potato *(Ipomoea batatas)* is a major source of carbohydrate for millions of people, especially in developing countries. It is grown for its edible tuberous roots which contain about 27% carbohydrate and high concentrations of vitamin A, C, calcium and iron (Nedunchezhiyan *et al.*, 2011, Varmudy, 2014). The leaves of sweet potato are used as fodder and for culinary purposes. Sweet potato vine is a valuable source of green fodder too and lasts throughout off-season. It is well known for drought tolerance. Mid-season and terminal droughts can reduce the sweet potato yield but there is no chance of crop failure (Nedunchezhiyan *et al.*, 2010). In India it is grown in all states and Odisha being top in area as well in production (Vanitha *et al.*, 2013). As it is grown in most of the districts in Odisha, farmers are raising local cultivars with traditional cultivation practices. Therefore, average productivity of sweet potato in Odisha is only 9.3 t/ha compared to the Asian average of 15 t/ha and 40% of USA and China (Fig. 1).

The traditional sweet potato cultivars raised in Koraput region are poor performers in term of yield and nutrition. Likewise, farmers commonly use old degenerated planting material without any vine treatment; along with imbalanced use of fertilizers. These are major constraints leading

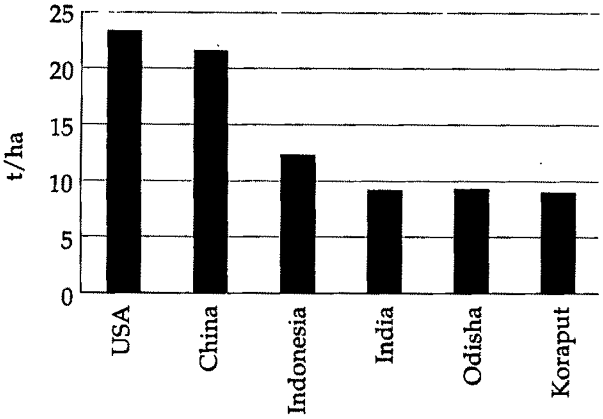

Fig. 1. Sweet potato productivity among top cultivating countries.

to poor harvest. Thus, there is tremendous opportunity for increasing the productivity of sweet potato using improved cultivars and techniques. Koraput region of Odisha comes under eastern ghats of India receiving an average annual rainfall of 1450 mm. During south-west monsoon a larger chunk of medium sloping lands remains fallow despite of having good potential to support vegetable production even under heavy rainfall; otherwise leading to water erosion based soil-nutrient losses (Dass *et al.*, 2008). Farmers, who do not possess lowlands for paddy cultivation, cultivate sweet potato and exchange it for paddy. Hence, sweet potato is contributing as an important ingredient for barter system for food grain procurement. Due to religious significance there is a great demand for sweet potato during *Kartik* (November) month and it coincides with the harvest period, which fetches good remuneration to the farmers.

Breeding efforts for useful traits in sweet potato is done by Central Tuber Crop Research Institute (CTCRI), Bhubaneswar centre for developing varieties with high yield, starch and high beta-carotene (precursor of vitamin A) content. The CTCRI has to its credit the release of nearly 16 varieties of sweet potato (Abraham *et al.*, 2006). However, sweet potato productivity is low due to poor transfer of technologies from the research farms to the farmers' fields leading to extension gaps. To bridge these gaps front line demonstrations (FLD) programme is a vital tool for extension agencies. Therefore, FLD on sweet potato cultivation of newly released early maturing, high yielding and pest-disease resistant varieties *viz. Kishan* and *ST-14* may be helpful to boost its production alongwith nutritional security in this tribal region. The detailed characteristics of varieties are presented in table 1. These high yielding and nutritional rich varieties intended KVK-Koraput to conduct FLD's on sweet potato with objectives : (1) to evaluate the performance of high yielding sweet potato varieties on farmers' field under rainfed conditions and (2) to study the economics, extension gaps and adoption behavior for making appropriate agro-techniques *vis-à-vis* extension methodologies for higher adoption.

MATERIALS AND METHODS

A number of FLD's were conducted in different villages of Koraput district (latitude 19° 45' 30" N, longitude 82° 56' E and altitude 950 m above mean sea level) of Odisha during rainy season (June to October) of 2010-14. Climate of the study area is sub-tropical and sub-humid type with mean annual maximum and minimum temperature of 30.6 and 17°C, respectively. Mean annual rainfall of the area is 1450 mm, of which 80% is received during June to October. KVK conducted an investigation in the target area on assessing the performance of sweet potato varieties on sloping physiography. First of all, the constraints in sweet potato production were identified through participatory rural appraisal (PRA), farmer meetings, training programmes. Field diagnostic visits and questionnaires were conducted. Thus, based on the farmers' demand for a good variety, 60 FLD's were conducted in 6 villages of the Koraput district of Odisha.

Each FLD was piloted in an area of 400-800 m^2 in *Kharif* season (June-October) along with farmers practice (FP) in the same area. Sweet potato vine cuttings were raised in 2 stages *i.e.*, primary nursery of 50 m^2 for 45 days (March) and secondary nursery of 500 m^2 for 45 days (May) under irrigated conditions and thus 90 days old approximately 83,000 vine cuttings of 60 cm length were ready for transplanting. These vine cuttings were transplanted in the fields during second fortnight of June to second week of July every year. The vine cuttings were dipped in systemic insecticide (Fenthion@0.05%) for 10 minutes before transplanting to prevent the attack of sweet potato weevil. Before planting in the main field granular insecticide (phorate 10 G) was applied to reduce the incidence of the weevil and termite.

Before execution of FLD, each year training programmes were organized for the selected village farmers to impart the technological know-how on sweet potato cultivation. All other steps like site selection, layout of demonstrations, farmers' participation, *etc.* were followed as suggested by Choudhary (1999). The data were collected through survey method and major tools used were exhaustive village survey, interview schedules (structured and semi-structured), in-depth discussion and secondary data sources. Taking into consideration the scope and objectives of the study, a well-structured interview schedule was prepared. Based on the result of pre-test, suitable modifications were made and a final interview schedule was prepared. All the data were collected as per extension codes following Bhairamkar *et al.*, (2011) and tabulated for statistical analysis. The statistical tools and tests such as frequency, percentages, mean, and standard deviation were used wherever found appropriate and data were analyzed systematically to draw valid inferences.

The tuber yield of demonstrations as well as FP (local check) were recorded and analysed according to different parameters suggested by Verma *et al.* (2014). On the basis of prevailing market prices, income, technological and adoption gaps were calculated as following given details :

1. Extension gap = Demonstration yield — FP yield
2. Technology gap = Potential yield — Demonstration yield
3. Technology index = (Pi – Di)/ Pi × 100
   Where,
   Pi = Potential yield of i^{th} crop
   Di = Average demonstration yield of i^{th} crop.
4. Additional return = Demonstration return — FP return
5. Effective gain = Additional return (Ar) — Additional cost (Ac)
6. Increment B:C ratio = Ar/Ac

The adoption quotient was determined as; AQ = Sum of obtained score/ maximum possible adoption score*100. The rainfall data was collected form annual reports of IISWC, Research Center- Sunabeda (Anonymous, 2014).

RESULTS AND DISCUSSION

Rainfall pattern and crop establishment

On an average (2010-14), about 9, 17, 19, 13 and 6 rainy days aroused in June, July, August, September and October months, respectively. With the inception of monsoon in June heavy showers and gusty winds harshly affects sweet potato nursery. This affects the main crop yield with vine mortality leading to poor plant stand. Hence, care should be taken by thatching as well as creation of drainage facility in nursery. Adequate soil moisture availability was ensured with an average rainfall of 378 mm during vine cuttings transplanting in the field. At later stage of crop growth in August and September an average rainfall of 326mm and 292mm, respectively supported tuber formation and bulking stage of sweet potato. During this grand growth period rainfall volume was sufficient to

Table 1. Details of the ICAR-CTCRI released varieties

Variety	Yield and duration	Plant characteristics
Kishan	16-26 t/ha and 120 days	Clonal selection after polycross, long elliptic tubers with purple skin and white flesh. Suitable for rainfed as well as irrigated, medium to uplands and hilly areas. Released in 2005 for cultivation in Odisha state.
ST-14	16-19 t/ha and 110 days	Long elliptic tubers with cream skin and orange flesh. Suitable for rainfed as well as irrigated conditions. High beta carotene (13.2-14.4 mg/100 gm). Can tolerate salinity stress (6-8.0 dSm^{-1}), Released in 2009 for cultivation in Odisha state.

meet the irrigation demand. From this elucidation it can be concluded that benefit from the early rainfall should be taken by timely transplanting (2nd week of July) of vine cuttings for maximum yield.

Knowledge level of farmers

The knowledge level and perception of improved sweet potato cultivation was analyzed amid farmers of different villages. Farmers' feedback was categorized into low, medium and high categories based on the score. The total adoption score for each farmer was computed by adding up the scores of all 10 point package of practice of sweet potato cultivation (Table 2). Majority of the sweet potato cultivators were under category of medium score for both varieties *Kishan* (44%) and *ST-14* (42%). The reason attributed for high adoption score of variety *Kishan* can be its higher yield potential followed by *ST-14*. However *ST-14* has vitamin-A enriched characteristic which addresses the malnutrition issue among the tribal populace. Since, sweet potato is not cultivated on large scale and its cultivation is gradually picking up, few cultivators (42% for *Kishan* and 25% for *ST-14* variety) possessed high level of knowledge in this tribal region. From this analysis, it can be established that sweet potato cultivation has boosted confidence level of the cultivators in this area. Farmers are able to prioritize and adopt sweet potato varieties. This is an encouraging finding and further efforts should be made to bring the cultivators in high adoption category.

Table 2. Distribution of the sweet potato growers according to their adoption behaviour (N=60)

Adoption behavior	Variety	
	Kishan	ST-14
High (> 60)	15 (42)	6 (25)
Medium (40 to 59)	16 (44)	10 (42)
Low (< 40)	5 (14)	8 (33)
Total	36 (100)	24 (100)

Note : Figures within the parentheses are % to total farmers

Tuber yield

Tuber yield of both the improved cultivars was higher under demonstrations as compared to existing FP (Table 3). However, in comparison to potential yield only 70-72% yield was achieved as the main crop was raised under rainfed conditions. The increase in yield under demonstrations was in the range from 44 to 57% for variety *Kishan* and 19-23% in *ST-14*, respectively, over local cultivars. Attaluri *et al.* (2010) in their assessment deliberated on the reason of high yield of input responsive varieties *Kishan* and *ST-14* which are clonal selection and have enhanced photosynthetic efficiency and disease tolerance characters, also enriched with vitamin A. These characters lead to increased production and accumulation of carbohydrates with favorable effect on vegetative growth and yield. Evaluating same varieties, similar findings are reported by Nedunchezhiyan *et al.* (2008) during evaluation of sweet potato cultivars under sole as well as intercropping with rice, finger millet and maize.

Gap analysis

An extension gap ranging from 56-68 q/ha and 23-28 q/ha in yield was perceived between FLDs and FP throughout years for variety *Kishan*

Table 3. Sweet potato yield and gap analysis under front line demonstrations in farmers' fields

Variety	Year (*kharif*)	Yield (q/ha)			Increase over FP (%)	Extension gap (q/ha)	Technology gap (q/ha)	Technology index (%)
		Potential	Demonstration	Farmers practice (FP)				
Kishan	2010	260	182	126	44	56	78	30
	2011	260	188	120	57	68	72	28
	2012	260	189	125	51	64	71	27
ST-14	2012	190	145	122	19	23	45	24
	2013	190	147	121	21	26	43	23
	2014	190	148	120	23	28	42	22

and *ST-14*, respectively (Table 3). The average extension gap was 44 q/ha. The lowest extension gap was 56 q/ha in 2010 and 23 q/ha in 2012 for *Kishan* and *ST-14*, respectively which owed to higher yield under FP in the particular year. Whereas, the highest extension gap of 68 q/ha was obtained in 2011 and 28 q/ha in 2014 for *Kishan* and *ST-14*, respectively, this points towards poor yields due to weevil attack under FP. Overall, such gaps are attributed to improved planting material, healthy nursery, intercultural operations and adoption of improved production technology in the demonstrations.

Wide technology gaps were also observed during the course of demonstrations (Table 3). The technology gap of total 60 FLD's for tested varieties was on an average 74 and 53 q/ha for *Kishan* and *ST-14*, respectively; which is 32 and 40% of respective variety's potential yield. Generally, the technological gap appears even if the FLDs are conducted under the strict supervision of the scientists in the farmers' fields. This may be attributed mainly to ill distribution of rainfall, variation in soil fertility, variations in biotic and abiotic stresses observed across different plant growth stages. The study also showed a wide gap between the potential crop yields and demonstration yields, which suggests further refinement in generated farm technology. Therefore, location-specific crop management recommendations are needed to bridge the gap in potential and demonstration yields (Choudhary and Suri, 2014).

Technology index designates the feasibility of the evolved technology in the farmers' fields. Lower the value of technology index, higher is the viability of the improved technology. Technology index spun around 28% during the FLD's. Technology index for all the demonstrations during different years was in accordance with technology gap. Lower technology index (22 - 30%) reflected sufficient extensions services for transfer of technology. Still efforts should be made to bridge this gap with more farmers' friendly demonstration (Yadav *et al.*, 2014).

Economic analysis

Economics of sweet potato cultivation under FLD's was appraised on the then market prices. All the variable costs were considered in calculating the cost of cultivation and the detailed economic returns with incremental benefit : cost ratio (IBCR) are presented in Table 4. It imitates that owing to improved variety, vine treatment, fertilizers and other inputs; the cost of cultivation in demonstration plots was higher in comparison to FP. Average of three years' cost of cultivation was ₹ 41,817 and 41,833/ha for *Kishan* and *ST*-14, respectively. Monetary returns are a function of yield and market price which varied along the years but showed ascending trend in progressive years (2010-14). Mean values incites that Kishan variety noted more net returns (₹ 37,496) in comparison to *ST*-14 (₹ 30,070). In terms of yield best performer was *Kishan* (186 q/ha).

The average values marks that with a small hike in cost of cultivation, worthy net returns were obtained provided with better market projections. On similar lines, highest IBCR (22) was for variety *Kishan* in year 2011 and *ST*-14 (7) in 2014. Although *ST*-14 is registering low yields but its nutritional characteristics and flesh colour are preferred by customers. But, these traits are not popularized in marketing community which is an area of concern.

Table 4. Economic analysis of front line demonstrations in farmers' fields

Variety	Year	Cost of cultivation (₹ ha)		Net returns (₹ ha)		Add. cost in demo. (₹ ha)	Effective gain (₹ ha)	Incremental B:C ratio (IBCR)	Wholesale market price (₹ ha)
		Demonstration	FP	Demonstration	FP				
Kishan	2010	42,610	41,250	30,190	9,150	1,360	21,040	16	400
	2011	41,630	40,300	38,458	10,820	1,330	27,638	22	426
	2012	41,210	39,210	43,840	17,040	2,000	26,800	14	450
ST-14	2012	41,500	39,600	23,750	15,300	1,900	8,450	5	450
	2013	41,900	39,830	31,600	20,670	2,070	10,930	6	500
	2014	42,100	40,100	34,860	22,300	2,000	12,560	7	520

Table 5. Distribution of respondents on the basis of adoption score of recommended scientific packages of sweet potato cultivation (N=60)

Sl. no.	Recommended scientific practices	Adoption (%)			Total score obtained	Adoption quotient	Adoption category	Adoption rank
		Full	Partial	None				
1	Use of HYV varieties	15	35	10	125	69.4	Medium	III
2	Nursery management	45	15	0	165	91.7	High	I
3	Vine preparation (root proliferation)	5	38	17	108	60.0	Medium	VI
4	Vine cutting treatment (Fenthion @ 0.05%)	2	3	55	67	37.2	Low	VIII
5	Nutrient management	15	35	10	125	69.2	Medium	IV
6	Pest management (Phorate @ 10 kg/ha)	8	38	14	114	63.3	Medium	V
7	Weevil management by pheromone trap	0	4	56	64	35.6	Low	IX
8	Weeding and earthing up	40	20	0	160	88.9	High	II
9	Pruning for forage	2	18	40	82	45.6	Low	VII
10	Value addition and storage	0	3	57	63	35.0	Low	X

Enhanced fiscal returns in terms of gross, net and additional returns through improved farm technology have also been reported by Nedunchezhiyan *et al.* (2010). Overall, economic analysis showed that transfer of improved technology of sweet potato cultivation and its adoption can substantially enhance the productivity and farmers' profitability. This also can provides a better livelihood option and additional security for farmers under rainfed farming in tribal region of Odisha.

Adoption of sweet potato cultivation

Adoption of ten scientifically recommended practices of improved sweet potato cultivation was assessed on the feedback of respondents. Based on feedback score adoption quotient (AQ) was computed and ranking was done (Table 5). Data signposts that 40% of the recommended practices like adoption of HYV's, vine cutting preparation, nutrient management, pest management were adopted by the respondents mediocrely with AQ of 69.4, 60, 69.2 and 63.3, respectively. Critical practices like vine treatment, use of pheromone traps, pruning for forage production and value addition practices were largely missing from sweet potato cultivation. Nursery management and weeding practices were highly adopted by the respondents registering AQ to the tune of 91.7 and 88.9, respectively.

The low adoption of critical practices may be due to fact that pesticides, pheromone traps are costly and their availability to the farmers is difficult. Discarded forage value of sweet potato is attributed to problem of load transport to home. Whereas, limited value addition to sweet potato is ascribed to lack of knowledge and training. High adoption of nursery management and weeding-earthing practices is due to ease in availability of family labour. Respondents followed this labour intensive scientifically recommended practice most effectively. The result of this table indicates that there is a need to refine the technology and extension gaps in critical practices. The results corroborate the findings of Mbanso *et al.* (2012) and Pal *et al.* (2015).

CONCLUSIONS

During FLDs in 6 villages in tribal Koraput region of Odisha, an improved sweet potato varieties *Kishan* and *ST-14* were raised with scientific production technologies led to an increase of tuber yield by 45% over existing FP. That too with a meager incremental increase in cost of cultivation by ₹ 1563 and 1990/ha which even the small (progressive) and marginal farmers can afford. The mean extension gap (63 and 26 q/ha) and IBCR (18 and 6) for variety *Kishan* and *ST-14*, respectively are sufficiently high to motivate the farmers for adoption of improved cultivation. FLD program was also effective in changing attitude, skill and knowledge of vegetable growers towards adoption of sweet potato cultivation in the study area.

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Scaling-up of maize productivity, profitability and adoption through frontline demonstration technology-transfer programme using promising maize hybrids in Himachal Pradesh

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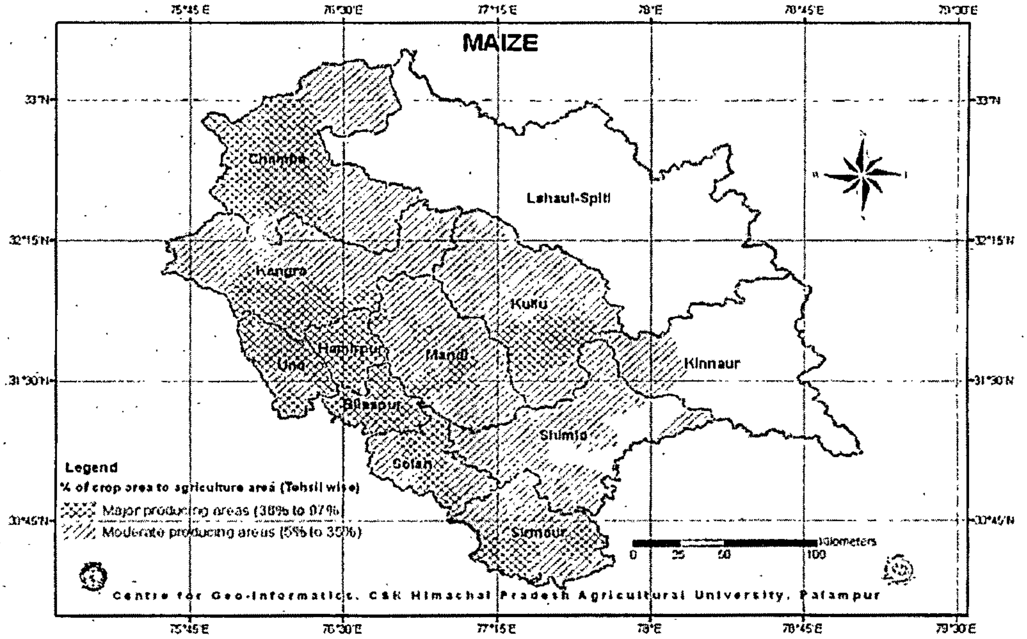
ABSTRACT

The evaluation of technology-transfer through frontline demonstrations (FLDs) on productivity and profitability of maize against farmers' practice was studied during *kharif* 2009-2014 in Mandi district of Himachal Pradesh (India). Out of 10 blocks of the district, 06 blocks viz. Sundernagar, Balh, Gohar, Karsog, Gopalpur and Dharampur were randomly selected. Six maize hybrids viz. Proagro-4642, Proagro-4640, Double Dekalb, KH-717, PG-2414, Bisco-855 and one single cross hybrid (HQPM-1) alongwith SAU recommended technology were demonstrated in 50 ha area comprising 441 farmers from 35 villages of these 6 blocks. The study revealed that with the transfer of improved technology under FLD's on maize, the grain yield of demonstration plots was considerably higher over farmers' plot yields. The studies indicated that by adopting the improved maize production technology, the magnitude of yield increase in FLD's over farmer's plot was 26.6, 18.6, 33.5, 35.7, 25.3, 30 and 21.8% in Proagro-4642, Proagro-4640, Double Dekalb, KH-717, PG-2414, Bisco-855 and HQPM-1, respectively. Improved technology package also improved the profitability in terms of gross and net returns besides benefit: cost ratio (BCR) ranging from 1.26 to 1.58. The study also revealed a wide extension gap (609-938 kg ha^{-1}) between the demonstration yields and farmers' plot yields for various maize hybrids. Therefore, there is a need to aware and educate the farmers through trainings and demonstrations for adoption of improved technology besides ensuring availability of critical inputs well in time so as to abridge yield gaps in maize in Himachal Pradesh.

Key words: Frontline demonstrations, Maize, Productivity, Profitability, Technology-transfer, Yield gaps.

Agricultural production is the mainstay of Indian agricultural economy as the majority of the population depends on agriculture for employment and livelihoods. Rapidly increasing population and emerging production vulnerabilities spell out an urgent need for enhancing and sustaining productivity of land through cereal food production systems (Choudhary *et al.*, 2013a; Pooniya *et al.*, 2015). Under such situation, maize (*Zea mays* L.) appears to be a potential cereal crop because of its highest genetic yield potential over other cereals and its suitability to diverse climates and management practices; that's why it is known as queen of cereals (Kumar *et al.*, 2015). Maize occupies 3rd position both in area and production after rice and wheat in India. The products from the speciality maize types like pop corn, baby corn and sweet corn have the great demand in the cities/towns. It is also a good feed for poultry and piggery besides it furnishes huge quantities of green fodder for cattle. Several industries like starch, milling, *etc.* are based on its products and by-products.

Maize is major *Kharif* crop of Himachal Pradesh with an average yield of 25.5 q ha^{-1} (Choudhary *et al.*, 2013a). In Himachal Pradesh, Shivalik and Himalayan foothill region constitute main conventional maize production areas covering Mandi, Kangra, Hamirpur, Chamba, Bilaspur, Kullu, Solan and Sirmour districts (Fig. 1). However, recent studies have revealed that wet-temperate region of the state also have ample scope for maize area expansion which would harness higher maize yields (Fig. 2). Himachal Pradesh has made a remarkable progress in the maize production during last 6 decades, owing to favourable agro-climatic conditions, sufficient rainfall during *Kharif* season, adoption of improved technology besides great production potential of maize in the state (Choudhary *et al.*, 2013a). In Himachal Pradesh, highest area and production of maize is found in Mandi district followed by Kangra, Hamirpur, Chamba and Bilaspur, respectively. In Mandi district, it is grown in an area of 48681 ha with an average yield of 28.2 q ha^{-1} (Choudhary *et al.*, 2013a). Although, the maize productivity in the district is quite higher than the national and state averages, but still there is a scope to increase its yield to desired level, which may be achieved by the adoption of recommended farm technology. Lack of suitable high yielding varieties/hybrids as well as poor knowledge about production practices are the main reasons for low productivity of maize in the district (Choudhary *et al.*, 2015). The productivity of maize per unit area could be increased by adopting the SAU recommended farm technology. Thus, frontline demonstrations (FLDs) using promising maize hybrids were conducted during 2009-14 in the district. Under FLD programme, the field demonstrations are conducted under close supervision of scientists to demonstrate the production and protection technologies using newly released cultivars/hybrids alongwith crop management practices at the farmer's fields in different farming situations to generate the production data and feedback (Choudhary, 2013). The main purpose of conducting FLDs is to convince the farmers as well as extension personnel about the potentialities of the technologies for further adoption and diffusion on large scale for the benefit of farming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Hamirpur
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Mandi
Kinnaur
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Solan
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% of crop area to agriculture area (Tehsil wise)
Major producing areas (38% to 87%)
Moderate producing areas (5% to 35%)
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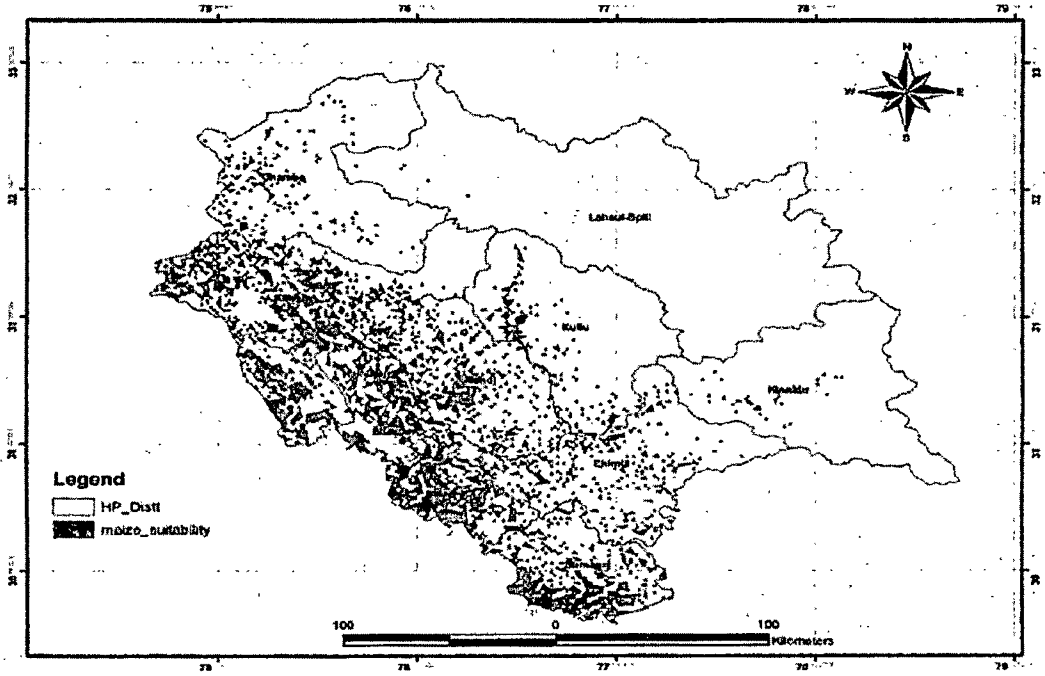
Centre for Geo-Informatics, CSK Himachal Pradesh Agricultural University, Palampur

(Source : www.hillagric.ac.in)

Fig. 1. Conventional maize production areas in Himachal Pradesh.



(Source : www.hillagric.ac.in)

Fig. 2. Maize suitability areas in Himachal Pradesh.

community (Choudhary *et al.*, 2012, 2013b, 2015). Thus, keeping in view the above facts, the present study was undertaken to enhance the productivity, profitability and technology adoption through FLDs on maize in Himachal Pradesh.

MATERIALS AND METHODS

Study area

The study was conducted in the Mandi district of Himachal Pradesh (India) under rainfed farming situations. Initially during 2008, a participatory rural appraisal (PRA) exercise was conducted and critical gaps between conven-tional and improved maize production technology were worked out and prioritized (Table 1). Later on based on the critical gaps identified through PRA, frontline demonstrations (FLDs) on improved production technology on maize were conducted. Out of total 10 develop-mental blocks, six blocks *viz.* Sundernagar, Balh, Gohar, Karsog, Gopalpur and Dharampur were randomly selected for above purpose. A total of 50 ha area comprising 441 farmers from 35 villages of these 06 blocks were randomly selected for conducting FLDs on promising maize hybrids during *kharif* 2009-2014. Trainings on improved maize production technology were imparted before conducting demonstrations. Six improved maize hybrids from private sector *viz.* Proagro-4642, Proagro-4640, Double Dekalb, KH-717, PG-2414, Bisco-855 and one single-cross hybrid (HQPM-1) from public sector were taken for assessing their potentialities at selected maize growers under FLD programme. In FLD's plot, SAU reco-mmended package of practices was adopted and critical inputs *i.e.* seed, fertilizers, herbicide, pesticide, etc. were either supplied to the selected farmers by the CSKHPKV, KVK, Mandi (HP) or invested by farmers whereas, adjoining field of farmers were taken as control/ local check, where the crop was grown according to farmers' practice (Table 2). Time to time regular consultancy was provided to selected FLD's plot farmers. Required data was collected through well structured schedule developed for the purpose by regular monitoring of demonstration fields as well as personal interactions with the farmers. The data so collected was tabulated and analyzed for required interpretations. The key indicators of evaluation are crop yield comparison under FLD and its economics.

Table 1. Gap in adoption of improved maize production technology under rainfed farming situations of Himachal Pradesh

Sr. No.	Items of package	Recommended practice	Existing practice	Gap in adoption (F/P/N)*
1.	Sowing time	May-June	May-June	N
2.	Sowing method	Line sowing	Broadcast	F
3.	Varieties	Hybrid/Composites	Any hybrid	F
4.	Seed rate/ha	20 kg/ha	20 - 25 kg/ha	P
5.	Seed treatment	Carbendazim 50 WP @ 2.5 g/kg seed	Not done	F
6.	Organic manures (t/ha)	10-15 t/ha	12.5 t/ha	N
7.	Fertilizers (NPK kg/ha)	120:60:40	33.25:12.0:6.0	P
8.	Method of fertilizer use :			
	Basal (NPK)	In rows	Not done	F
	Top dress (N)	Spot/Band application	Spot application	N
9.	Weed management :			
	Mechanical	Weeding/hoeing	Done	N
	Herbicides	Atrazine 50 WP @ 2-2.5 kg/ha	Not done	F
10.	Pest management :			
	Cutworms	Chlorpyriphos	Not done	F
12.	Average yield (q/ha)	40-45 q/ha	20-25 q/ha	P

*F= Full gap; P= Partial gap; N= No gap

Table 2. Technology demonstration package and farmers' practice under FLD's in maize during 2009-14.

Technology component	Demonstration plots	Farmers' practice
Maize hybrids	Proagro-4642, , Proagro-4640, Double Dekalb, KH-717, PG-2414, Bisco-855, HQPM-1	Any hybrid/local strain
Seed rate	20 kg ha^{-1}	20-25 kg ha^{-1}
Sowing method	Line sowing (60×20 cm)	Broadcasting
Weedicide	Atrazine 50 WP @ 2.5 kg ha^{-1}	Nil
Fertilizer dose	NPK @ 120:60:40 kg ha^{-1}	NPK @ 33.25:12.0:6.0 kg ha^{-1}
Plant Protection	Seed treatment (Carbendazim @ 2.5 g kg^{-1} seed)	Nil
Technical guidance	Time to time	Nil

The yield increase in demonstrations over farmers' practice was calculated using the following formula (Choudhary *et al.*, 2009):

% increase in yield over farmers' practice (% YIOFP) =

$$\frac{\text{Demonstration yield-farmers' plot yield}}{\text{Farmers' plot yield}} \times 100$$

Estimation of extension gap

The estimation of extension gap was done using following formula (Choudhary *et al.*, 2009).

Extension gap = Demonstration plot yield – Farmer's plot yield.

Economic analysis of FLD's

Cost of cultivation *i.e.* cost of seed, FYM, fertilizers, pesticides, labour charges etc. was taken into consideration in the present study. For calculating the actual labour requirement for the particular farm operation alongwith its cost, the norms developed by CSKHPKV, Palampur were followed. The gross and net returns were worked out accordingly by taking cost of cultivation and price of grain and straw yield of respective maize hybrids into consideration. Similarly, the benefit-cost ratio (BCR) was worked out as a ratio of gross returns and corresponding gross costs (Choudhary *et al.*, 2009).

RESULTS AND DISCUSSION

Gap in adoption

Critical gaps worked out through PRA exercise has been presented in Table 1. It is evident that full gap was observed in practices such as sowing methods, improved varieties, seed treatment, method of basal dose application, chemical weed and pest management. The study also indicated partial gap in seed rate and dose of fertilizers. Overall, 50-55% yield gap was observed in maize due to non-adoption of SAU recommended technology. The reason for non-adoption of recommended technologies might be due to the lack of awareness and less exposure to information sources (Yadav *et al.*, 2012, 2013). Non availability of critical inputs in time might be the other possible reason for non-adoption of recommended technologies (Choudhary, 2013). Therefore, extension agencies should make their efforts towards skill development of farmers and the input supply system should be strengthened and streamlined (Dass *et al.*, 2002; Choudhary *et al.*, 2009).

Grain yield

With the transfer of technology under FLD's on maize, the grain yield of demonstration plots was considerably higher than the farmers' plot yields (Table 3) which could be due to the adoption of SAU recommended technology in FLD's during the study period (Choudhary, 2013). The yield of demonstrated hybrid plots over farmers' plots was lowest in PG-2414 (3288 kg/ha) followed by Proagro-4640 (3321 kg/ha). The highest yield was observed in Double Dekalb hybrid (3738 kg/ha) followed by KH-717 (3563 kg/ha) and Proagro-4642 (3545 kg/ha). The public sector single cross hybrid (HQPM-1) provided grain yield of 3409 kg/ha. This shows that with the adoption of improved technology, the higher yields can be obtained. The magnitude of yield increase in FLD's over farmer's plot yields was in the range of 18.6 to 35.8%. Similar yield enhancement in different crops in FLDs' has been documented by various workers (Dhaka *et al.*, 2010; Kumar *et al.*, 2010). From these results, it is evident that the performance of demonstrated technology was found better than the local check under local conditions. Farmers were motivated by encouraging results of agro-technologies applied in the FLDs for better technology adoption in the region.

Yield gaps

The yield gap in present study was worked out in terms of extension gap (Fig. 3). Maximum extension gap of 939 kg/ha was observed in Double Dekalb hybrid followed by Proagro-4642 (745 kg/ha) while lowest extension gap of 521 kg/ha was seen in Proagro-4640. Lower extension gap indicates more popularity among the farmers whereas higher extension gap might be due to less awareness about the improved technology. The higher extension gap indicates that there is a strong need to motivate the farmers in adoption of improved technology over their local practice. Extension gaps in field demonstrations have also been observed by various workers in Himachal; Pradesh (Vedna *et al.*, 2007; Choudhary *et al.*,

Table 3. Performance of different maize hybrids demonstrated under FLDs in Mandi district of Himachal Pradesh during 2009-14

Maize hybrids	Area (ha)	Number of farmers	Yield (kg ha^{-1})		% YIOFP***
			DP*	FP**	
Proagro-4642	2.0	19	3545	2800	26.6
Proagro-4640	2.0	15	3321	2800	18.6
Double Dekalb	4.0	35	3738	2800	33.5
KH-717	20.0	205	3563	2625	35.7
PG-2414	10.0	78	3288	2625	25.3
Bisco-855	10.0	67	3413	2625	30.0
HQPM-1	2.0	22	3409	2800	21.8

* DP - Demonstration Plot, **FP - Farmers' Plot, ***YIOFP - Yield increase over farmers' practice.

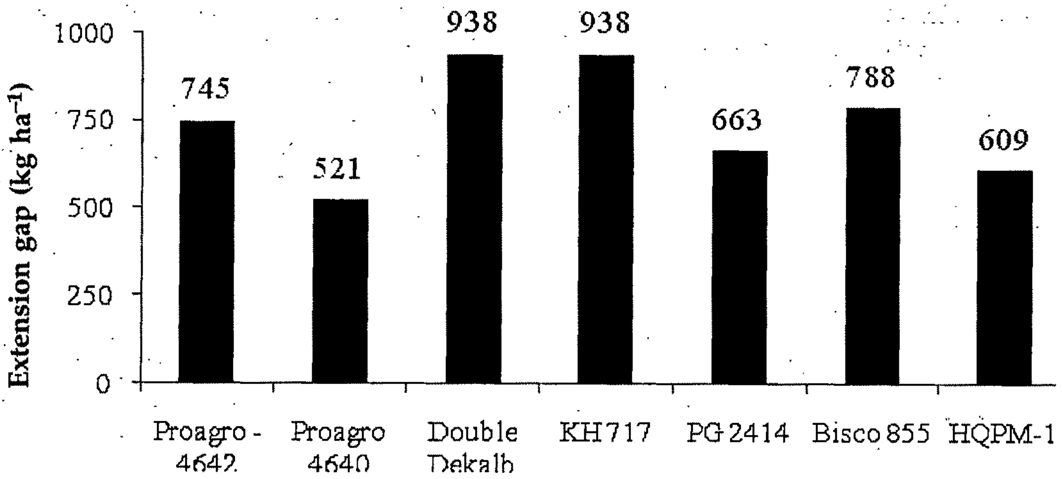


Fig. 3. Extension gap in the different maize hybrids demonstrated under FLDs in Himachal Pradesh

2013b; Choudhary, 2013); which might be attributed due to lack of awareness in the adoption of improved and recommended technology (Choudhary et al., 2015).

Economic analysis

The cost of production of improved technology varied between Rs. 25307 to 26010/ ha (Table 4). The net returns in demonstration plots was highest in Double Dekalb hybrid followed by HQPM-1 compared with the farmers' plots. Proagro-4642 and Proagro-4640 hybrids provided the net returns of ₹ 13557 and ₹ 11224/ ha, respectively. Similarly, highest BCR (1.58) was observed in Double Dekalb followed by HQPM-1 (1.58), while lowest BCR (1.26) was recorded with PG-2414 hybrid. A feedback was also taken from the farmers which showed that they liked the performance of Proagro-4642, Double Dekalb and HQPM-1 hybrids; however, non-availability of seeds of these hybrids on subsidized rates through state government is a matter of concern. It is therefore inferred that seed subsidy on these hybrids in the region would boost the maize productivity. Overall, it is concluded that with use of improved maize production technology, the profitability and economic viability had substantially increased over farmers' practice. These results are in accordance with the findings of other workers (Choudhary et al., 2013b; Hiremath and Nagaraju, 2009; Dhaka et al., 2010).

CONCLUSION

Overall, it is concluded that there is a wide gap between the demonstration yields and

Table 4. Economic analysis of FLD's on maize in Mandi district of Himachal Pradesh during 2009-14.

Maize hybrids	Cost of cultivation (₹ ha^{-1})		Gross returns (₹ ha^{-1})		Net returns (₹ ha^{-1})		BCR*
	DP	FP	DP	FP	DP	FP	
Proagro-4642	25438	20000	38995	25200	13557	5200	1.54
Proagro-4640	25307	20000	36531	25200	11224	5200	1.44
Double Dekalb	26010	20000	41118	25200	15108	5200	1.58
KH-717	26010	20000	35630	26250	9620	6250	1.37
PG-2414	26010	20000	32880	26250	6870	6250	1.26
Bisco-855	26010	20000	34130	26250	8120	6250	1.31
HQPM-1	26010	22000	40908	33600	14898	11600	1.57

* BCR- Benefit: cost ratio

farmers' plot yields w.r.t. maize production technology. The study highlights that use of SAU recommended farm technology coupled with better crop management, the maize productivity and profitability can be enhanced under favourable agro-climatic conditions of the Himachal Pradesh even under rainfed situations. Further, Proagro-4642, Double Dekalb and HQPM-1 hybrids are best performer hybrids in the region. In nutshell, there is urgent need to aware and educate the hill farmers through FLD technology-transfer programme in maize coupled with promising maize hybrids to abridge the yield gaps in Himachal Pradesh.

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Gene action for important fruit characters in brinjal (*Solanum melongena* L.)

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ABSTRACT

Generation mean analysis was carried out to assess the presence of inter-allelic interaction and to estimate the importance of various gene effects for inheritance of six fruit characters in brinjal *viz.*, fruit length, fruit diameter, average fruit weight, total number of fruits per plant, early yield per plant and yield per plant. Six generations of five families were used for the study. Family wise estimates of gene effects and type of epistasis were summarized for all six characters. Scaling test revealed that all four types of scales (A, B, C and D) showed highly significant effect along with the high values of chi-square (χ^2). Both tests (scaling and chi-square) proved that the six parameter models were adequate for the estimation of gene effects. The joint scaling tests for these characters showed varied values of gene effects in families for all types of gene effects *viz.* Additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) for different traits. Almost all characters showed duplicate dominance type of epistasis. Based on these results, inter-mating among selected individuals through recurrent selection and diallel selective mating system could be an alternative method for improvement of these traits of brinjal.

Key words: Brinjal, gene action, epistasis, generation mean analysis, scaling test

Brinjal (*Solanum melongena* L.) is one of the major vegetable crops in India, China and several other countries of Asia, Africa and Europe. China is the largest brinjal producer in the world followed by India with the productivity of 17.2 t ha^{-1} (NHB 2010), which is very low as compared to China's productivity of 35.7 t ha^{-1} (FAO, 2011). High yielding variety/hybrids are always in demand with locally desired specific fruit characteristics. Therefore, breeders are usually interested to develop such a variety/hybrid that fulfil the local demand with high yield and desirable fruit characters. Nature of gene action for fruit characters (Sharma *et. al.*, 2001) in Brinjal is important to decide breeding methods and is always helpful to the breeders while designing a breeding procedure. In brinjal, fruit characters are always most desirable objective for effective breeding methods. Its shape, size and colour have high local preferences. Their specific genotype suited for specific localities in India is the characteristic features of brinjal. It is not possible to have a common fruit characters suited to different localities. Fruit characters in brinjal are most considerable traits to develop a variety for specific locality. Thus, the knowledge of gene effects for fruit characters is very much important and is always desirable for effective breeding methods to get a viable output (Sharma *et. al.*, 2001). The present investigation was carried out to generate information about gene effects on fruit characters of five brinjal families for 6 generations.

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MATERIALS AND METHODS

The field trial was conducted at Vegetable Research Centre (VRC), G. B. Pant University of Agric. & Tech., Pantnagar (India) during *autumn-winter* seasons. Pantnagar is geographically situated at an altitude of 243.84 m above mean sea level and at 29°N latitude and 79.3°E longitudes. This falls in the humid sub-tropical zone and situated in the *Tarai* belt in the foothills of *Shivalik* range of the great Himalayas. Maximum temperature ranges from 32°C to 43°C in summer and minimum temperature ranges from 0°C to 9°C in winter. Frost can be expected from last week of December to first week of February. Soil of the field was clay-loam in nature and rich in organic matter.

The materials for present investigation were derived from a set of 8 × 8 diallel crossing (Method-II) during 2009-10. A total of seven genotypes of *Solanum melongena viz.*, BARI, PB-66, Pant Rituraj (PR), WB-1 (Land race of W. Bengal), PB-67, PB-71 and Pant Samrat (PS) and one genotype of *S. aethiopicum* were used for crossing programme. Evaluation of all parents and F1s (total 36 genotypes) was done during *autumn-winter* season of 2010-11. Five promising crosses *viz.*, BARI × PR, BARI × PB-67, BARI × PS, PR × PB-71 and WB-1 × PB-67 were selected for the development of five different families. These selected F_1s were back crossed with both the parents to generate B_1 & B_2 progenies and to develop F_2 generation of all five crosses. Thus, six generation (P_1, P_2, F_1, F_2, B_1 and B_2) of each were obtained from five different families. In the year, 2011-12 all five families were planted in the Randomized Block Design (RBD) in three replications. One month old seedlings were transplanted with a spacing of 75 cm × 60 cm in each of 6 m row length. The parental genotypes (P_1, P_2) and F_1 were transplanted in single row consisting of 10 plants for each replication, whereas, backcrosses (B_1 and B_2) were transplanted in three rows consisting of 30 plants and F_2s were transplanted in five rows consisting of 50 plants for each replication. Recommended package of practices were followed for raising the normal crops. Data was recorded on yield and fruit characters *viz.*, fruit length (cm), fruit diameter (cm), average fruit weight (g), total number of fruits per plant, early yield per plant (kg) and yield per plant (kg). Mean and variances were calculated for each generation using the data recorded on individual plants in each replication. Generation mean analysis was done on these five families to estimate gene effects for fruit characters as well as fruit yield. Data were subjected to individual scaling test as given by Mather (1949) and Hayman and Mather (1955), who devised four simple scaling test *viz.*, A, B, C, and D, for the detection of presence or absence of epistasis. Cavalli (1952) joint scaling test was used for the precise estimates of different parameters. Due to non-allelic interaction three parameters model was inadequate for scaling test. The goodness of fit was tested by chi-square (χ^2); *i.e.* the number of available generations minus the number of estimated parameters (Cukadar-Olmedo and Miller, 1997). The significance of parameters was tested with related standard errors at 1% and 5% probability levels. High values of chi-square at three degree of freedom were suitable for the weighted least square technique of Jinks and Jones (1958). The data were analysed by six generation mean analysis (Hayman, 1958).

RESULTS AND DISCUSSION

Simple scaling test *viz.*, A, B, C and D for all the six characters are presented in the table1 for family-1 (BARI × PR), family-2 (BARI × PB-67), family-3 (BARI × PS), family-4 (PR × PB-71) and family-5 (WB-1 × PB-67). Results indicated that all the four scales were highly significant for all six characters studied, which indicated the presence of non-allelic interaction for all the characters. High estimates of chi-square (χ^2) (Table 1) also indicate the presence of non-allelic interaction and inadequacy of three parameters model. Therefore, six parameters model seems applicable for all six traits to estimate the gene effects for all families which were under taken under study.

For the precise estimate of different parameters, joint scaling test (Cavalli, 1952) was used. The mean analysis was done for each

Table 1. Scaling test for different families of brinjal.

Family	Characters	A	B	C	D	Chi^2 at 3 d. f. (weighted)	Adequate model
Family-1 (BARI × PR)	Fruit length (cm)	-6.500**	4.500**	-4.647**	-1.323**	2788.722	6
	Fruit diameter (cm)	-2.820**	-3.757**	0.203	3.390**	8352.76	6
	Average fruit weight (g)	-137.707**	-234.470**	-238.897**	66.640**	4015.223	6
	Total number of fruits^{-1} plant	-7.243**	-6.820**	-15.317**	-0.627*	278.54	6
	Early yield/plant^{-1} (Kg)	-0.157**	-0.090**	-0.306**	-0.029**	1246.417	6
	Yield/plant^{-1} (kg)	-292.887**	-544.993**	30.400	434.140**	8648.383	6
Family-2 (BARI × PB-67)	Fruit length (cm)	-10.407**	-4.667**	9.313**	12.193**	7953.203	6
	Fruit diameter (cm)	-0.518**	-0.036	4.069**	2.312**	2623.249	6
	Average fruit weight (g)	-83.160**	13.413*	35.307**	52.527**	2879.216	6
	Total number of fruits/plant^{-1}	-13.983**	-13.357**	-12.467**	7.437**	1985.022	6
	Early yield/plant^{-1} (Kg)	-0.161**	-0.111**	-0.122**	0.075**	846.353	6
	Yield/plant^{-1} (kg)	-1.318**	-2.452**	0.137	1.953**	8632.479	6
Family-3 (BARI × Pant Samrat)	Fruit length (cm)	-11.087**	-8.300**	29.780**	24.583**	9049.731	6
	Fruit diameter (cm)	-0.918**	-0.947**	0.467**	1.166**	1987.427	6
	Average fruit weight (g)	26.007**	38.643**	-104.763**	-84.707**	2222.301	6
	Total number of fruits^{-1}/plant	-21.683**	-28.720**	-41.177**	4.613**	4355.812	6
	Early yield/plant^{-1} (Kg)	-0.001	0.030**	-1.147**	-0.588**	53279.84	6
	Yield/plant^{-1} (kg)	-2.371**	-1.634**	-2.404**	0.800**	6476.368	6
Family-4 (Pant Rituraj × PB-71)	Fruit length (cm)	3.600**	-1.640**	5.867**	1.953**	522.26	6
	Fruit diameter (cm)	-6.157**	-4.440**	-2.250**	4.173**	19561.088	6
	Average fruit weight (g)	34.893**	7.597*	-224.137**	-133.313**	4407.764	6
	Total number of fruits^{-1}/plant	-2.717**	-17.023**	-31.380**	-5.820**	2339.277	6
	Early yield/plant^{-1} (Kg)	-0.308**	-0.271**	-0.784**	-0.102**	1294.795	6
	Yield/plant^{-1} (kg)	-0.283**	-2.070**	-3.300**	-0.474**	2713.551	6
Family-5 (WB-1 × PB-67)	Fruit length (cm)	0.613**	1.507**	1.173**	-0.473*	44.953	6
	Fruit diameter (cm)	-1.593**	-0.767**	4.713**	3.537**	4910.138	6
	Average fruit weight (g)	154.997**	258.317**	-27.980**	-220.647**	13197.409	6
	Total number of fruits^{-1}/plant	-15.383**	-18.053**	-14.870**	9.283**	3698.317	6
	Early yield/plant^{-1} (Kg)	-0.022**	0.004	0.176**	0.097**	366.868	6
	Yield/plant^{-1} (kg)	-1.302**	-1.455**	0.768**	1.762**	15569.381	6

*, **: Significant at 0.05 and 0.01 probability level, respectively.

character in each cross using six parameter models. Results of joint scaling test are presented in the table 2 for all six characters. This revealed that the additive, dominance and epistatic gene effects were predominant in the desired direction for all the characters studied.

Character wise scaling test indicated that the presence of gene interaction *viz.*, additive (d), dominance (h), additive × additive (i), additive × dominance (j) and dominance × dominance (l) were significant for fruit length (cm) for all families except, family-1 (BARI × PR), where dominance (h) and dominance × dominance (l) were non-significant. The gene effects dominance (h) and dominance × dominance (l) took opposite sign indicating the presence of duplicate dominance epistasis in the inheritance of fruit length in all families except for family-1 (BARI × PR), where complementary recessive type of epistasis was pre-dominant. Similar results were reported by Thangavel *et al.* (2011), Singh *et al.* (2002) and Biradar *et al.* (2005). Scaling test for fruit diameter (cm) in all families showed highly significant effects indicating the presence of all five types of gene effects *viz.*, additive (d), dominance (h), additive × additive (i), additive × dominance (j) and dominance × dominance (l). The gene effects dominance (h) and dominance × dominance (l) took opposite sign indicating the

Table 2. Estimates of gene effects and interactions along with standard error and type of epistasis in brinjal.

Character	Families	M	D	h	I	j	L	Type of epistasis
Fruit length (cm)	Family-1	19.837**	13.017**	-1.090	2.647**	-11.000**	-0.647	
	(BARI × PR)	±0.583	±0.090	±1.718	±0.576	±0.583	±1.159	Complimentary
	Family-2	50.537**	9.35**	-67.597**	-24.387**	-5.74**	39.46**	
	(BARI × PB-67)	±0.300	±0.085	±0.809	±0.288	±0.272	±0.616	Duplicate
	Family-3	75.650**	9.017**	-122.003**	-49.167**	-2.787**	68.553**	
	(BARI × PS)	±0.706	±0.090	±1.891	±0.700	±0.582	±1.215	Duplicate
	Family-4	15.407**	-2.033**	-6.753**	-3.907**	5.240**	1.947**	
	(PR × PB-71)	±0.301	±0.083	±0.902	±0.289	±0.309	±0.790	Duplicate
	Family-5	12.220**	-3.633**	7.980**	0.947**	-0.893**	-3.067**	
	(WB-1 × PB-67)	±0.377	±0.049	±1.058	±0.374	±0.342	±0.698	Duplicate
Fruit diameter (cm)	Family-1	13.472**	-3.025**	-20.362**	-6.780**	0.937**	13.357**	
	(BARI × PR)	±0.102	±0.012	±0.272	±0.101	±0.081	±0.193	Duplicate
	Family-2	9.023**	-0.733**	-10.534**	-4.623**	-0.482**	5.177**	
	(BARI × PB-67)	±0.142	±0.025	±0.395	±0.140	±0.130	±0.258	Duplicate
	Family-3	5.965**	0.033**	-6.527**	-2.331**	0.029	4.196**	
	(BARI × PS)	±0.075	±0.012	±0.222	±0.074	±0.075	±0.154	Duplicate
	Family-4	16.672**	1.392**	-27.748**	-8.347**	-1.717**	18.943**	
	(PR × PB-71)	±0.099	±0.019	±0.279	±0.097	±0.092	±0.201	Duplicate
	Family-5	12.890**	0.683**	-17.423**	-7.073**	-0.827**	9.433**	
	(WB-1 × PB-67)	±0.110	±0.024	±0.315	±0.107	±0.104	±0.243	Duplicate
Average fruit weight (g)	Family-1	306.945**	-18.255**	-548.725**	-133.208**	96.763**	505.457**	
	(BARI × PR)	±5.368**	±0.883	±14.260	±5.295	±4.235	±10.773	Duplicate
	Family-2	260.53**	-0.067	-273.12**	-105.053**	-96.573**	174.80**	
	(BARI × PB-67)	±6.00	±0.762	±17.115	±5.952	±5.593	±11.381	Duplicate
	Family-3	-42.282**	28.278**	459.415**	169.413**	-12.637**	-234.063**	
	(BARI × PS)	±4.739	±0.882	±13.926	±4.656	±4.789	±9.410	Duplicate
	Family-4	-71.305**	-3.402*	604.962**	266.627**	27.297**	-309.117**	
	(PR × PB-71)	±5.594	±1.461	±15.943	±5.400	±5.649	±10.663	Duplicate
	Family-5	-299.070**	-13.320**	1307.517**	441.293**	-103.32**	-854.607**	
	(WB-1 × PB-67)	±4.231	±0.880	±11.095	±4.139	±3.451	±7.804	Duplicate
Total number of fruits/plant^{-1}	Family-1	13.018**	3.852**	-8.362**	1.253*	-0.423	12.810**	
	(BARI x PR)	±0.577	±0.199	±1.353	±0.542	±0.433	±1.073	Duplicate
	Family-2	34.613**	-1.617**	-57.993**	-14.873**	-0.627	42.213**	
	(BARI x PB-67)	±0.512	±0.375	±1.577	±0.349	±0.792	±1.581	Duplicate
	Family-3	36.422**	-9.072**	-72.785**	-9.227**	7.037**	59.630**	
	(BARI x PS)	±0.376	±0.264	±1.087	±0.269	±0.558	±0.922	Duplicate
	Family-4	2.387**	-3.607**	8.783**	11.640**	14.307**	8.100**	
	(PR x PB-71)	±0.449	±0.266	±1.192	±0.362	±0.574	±0.806	Complementary
	Family-5	36.292**	-3.632**	-69.052**	-18.567**	2.670**	52.003**	
	(WB-1 x PB-67)	±0.626	±0.328	±1.542	±0.534	±0.683	±1.085	Duplicate
Early yield/ plant^{-1} (kg)	Family-1	0.219**	-0.050**	0.026	0.059**	-0.067**	0.188**	
	(BARI x PR)	±0.006	±0.004	±0.015	±0.004	±0.008	±0.010	Complimentary
	Family-2	0.446**	-0.069**	-0.416**	-0.151**	-0.050**	0.423**	
	(BARI x PB-67)	±0.022	±0.003	±0.046	±0.022	±0.008	±0.025	Duplicate
	Family-3	-0.737**	-0.213**	2.293**	1.177**	-0.031**	-1.206**	
	(BARI x PS)	±0.008	±0.003	±0.024	±0.007	±0.009	±0.018	Duplicate
	Family-4	0.228**	-0.105**	0.081**	0.204**	-0.037**	0.376**	
	(PR x PB-71)	±0.009	±0.003	±0.025	±0.008	±0.008	±0.028	Complimentary
	Family-5	0.439**	-0.120**	-0.363**	-0.195**	-0.026*	0.213**	
	(WB-1 x PB-67)	±0.0104	±0.003	±0.036	±0.013	±0.011	±0.023	Duplicate
Total yield/ plant^{-1} (kg)	Family-1	3.524**	0.087**	-5.615**	-1.463**	0.708**	5.612**	
	(BARI x PR)	±0.071	±0.034	±0.173	±0.063	±0.073	±0.108	Duplicate
	Family-2	6.266**	-0.210**	-11.353**	-3.907**	1.134**	7.677**	
	(BARI x PB-67)	±0.057	±0.028	±0.158	±0.050	±0.065	±0.138	Duplicate
	Family-3	3.847**	-0.097**	-6.449**	-1.601**	-0.737**	5.605**	
	(BARI x PS)	±0.039	±.033	±0.128	±0.021	±0.069	±0.133	Duplicate
	Family-4	1.129**	-0.102**	-0.092	0.947**	1.786**	1.406**	
	(PR x PB-71)	±0.045	±0.029	±0.131	±0.034	±0.063	±0.114	Duplicate
	Family-5	5.672**	-0.422**	-9.830**	-3.525**	0.153**	6.282**	
	(WB-1 x PB-67)	±0.033	±0.015	±0.093	±0.029	±0.033	±0.109	Duplicate

*, **: Significant at 0.05 and 0.01 probability level, respectively.

presence of duplicate dominance epistasis in the inheritance in all families under study. These results are in accordance with the findings of Thangavel *et al.* (2011), Singh *et al.* (2002) and Biradar *et al.* (2005). For average fruit weight (g), gene effects were highly significant in all families except, for family-2 (BARI × PB-67) where, main effect additive (d) was found non-significant. In the family-1, 3, 4 and 5, the role of main effect (d) and (h) as well as interaction effects (i), (j) and (l) were significant, whereas, in the family-2, main effect (h) as well as interaction effects (i), (j) and (l) were significant. Duplicate dominant type of epistasis played a major role for average fruit weight in brinjal in all the families' studied. These findings are similar to the report presented by Thangavel *et al.* (2011), Singh *et al.* (2002) and Biradar *et al.* (2005). Scaling test also indicated highly significant effects for total number of fruits per plant for all types of gene effects except, for interaction effects (j) in the family-1 (BARI × PR) and family-2 (BARI × PB-67), where it was found non-significant. Role of main effects (d) and (h) as well as interaction effects (i), (j) and (l) were significant in the family-2, 3 and 4 whereas, in the family-1 and 2 main effects (d) and (h) as well as interaction effects (i) and (l) were significant. Duplicate dominant type of epistasis played important role for total number of fruits per plant in all the families except, for family-4 (PR × PB-71), where complimentary recessive type of epistasis was significant and indicating same sign on main effects (h) and interaction effect (l). Thangavel *et al.* (2011), Singh *et al.* (2002) and Biradar *et al.* (2005) also reported same trends regarding this trait.

Scaling test for early yield per plant (kg) was highly significant for all types of gene effects in all the families except, family-1 (BARI × PR), where main effect (h) was found non-significant. The main effects (d) and (h) as well as interaction effects (i), (j) and (l) were significant in all the families for this trait. Complimentary recessive type of epistasis was important in the family-1 and family-4 whereas, duplicate dominance type of epistasis were significant in the family-2, 3 and 5 for early picking of fruits in the brinjal. Similar type of result was observed by Singh *et al.* (2002). Yield per plant (kg) is the ultimate goal of any breeding programme. The knowledge of gene effects also plays an important role for designing of breeding procedure for high yield in brinjal. Thus, the scaling test was also considered for this trait. All five families for this trait were found highly significant effect for all five types of gene effects except, for main effect (h) in the family-4 (PR × PB-71), which was non-significant. Main effects (d) and (h) as well as interaction effects (i), (j) and (l) were important for this trait in the family-1, 2, 3 and 5. Duplicate dominant type of epistasis played an important role in all five families under study for the yield of brinjal fruits. Thangavel *et al.* (2011), Kathiria *et al.* (1998) and Biradar *et al.* (2005) also worked out and reported similar type of results for the gene effects of yield per plant in brinjal.

This investigation indicated that the importance of dominance and epistasis gene effects in the inheritance of six important characters taken in this study. Selection in early segregating generation may not be fruitful for these traits in brinjal. Whenever the dominance and epistatic effects will be disappearing in the advance/later segregating generation, selection may be useful. In this case inter-mating between selected individuals through recurrent selection will be more effective breeding procedure to improve these traits. Diallel selective mating (DSM) system may also be an alternative method for crop improvement of these traits in brinjal.

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Effect of plant growth regulators on growth, yield and economics of Indian mustard [*Brassica juncea* (L.) Czern & Coss] under rainfed condition

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ABSTRACT

A field experiment was conducted during winter *(rabi)* season of 2012-13 and 2013-14 at Chitrakoot, Madhya Pradesh to assess the effect of plant growth regulators on growth, yield and economics of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. Plant growth regulators *viz.* Naphthalene Acetic Acid (NAA) @ 50 and 100 ppm at 20 and 40 DAS and Cycocel (CCC) @ 50 and 100 ppm at 45 and 75 DAS alone and their combination were applied on mustard crop at various growth stages. Plant growth parameters *viz.* plant height, leaves/plant, dry matter/plant and yield attributes *viz.* siliquae /plant and 1000-seed weight were significantly enhanced due to application of NAA @ 100 ppm at 20 DAS followed by NAA @ 100 ppm at 40 DAS+ CCC @ 100 ppm at 75 DAS. However, root length and root spread were conspicuous higher under NAA @ 100 ppm at 40 DAS+ CCC @ 100 ppm at 75 DAS. Seed yield was recorded 23.4, 22.1 and 20.4 % greater under NAA @ 100 ppm at 20 DAS, NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS and NAA @ 50 ppm at 40 DAS than that of control, respectively. Stover yield was also obtained significantly higher under above treatment. Net returns and benefit: cost ratio was registered significantly more under NAA @ 100 ppm at 20 DAS and NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS.

Key words: CCC, economics, foliar application, Indian mustard, NAA, plant growth regulators, yield.

Rapeseed-Mustard is the most important oil seed crop accounting around 24.2 per cent of total oilseed production in India (Anonymous, 2014). Little enhancement in oilseeds production is not sufficient to cater the demand of growing population. However, the demand for oilseeds in India by 2020 is around 34 million tonnes. Therefore, to meet out demand of edible oil, it is essential to increase the productivity of mustard, which is very low as compared to productivity achieved in research trials. In rainfed condition, crop suffers from many adversities particularly frost, low or high temperature and moisture stress, which affect the physiological processes of crop, results in poor growth and yields. Plant growth regulators may be helpful in increasing the growth and productivity of mustard. The plant growth regulators are organic compounds other than nutrients, which modified plant physiological process, used for beneficial effects such as promoting root growth, increase number of flowers, fruit size and inducing early and uniform fruit setting and ripening. The effects of plant growth regulators are also influenced by light, temperature, moisture, nutrients and other environment considerably (Salunke *et al.* 2008). Foliar spray of 300 ppm Cycocel or 200 ppm ethrel on flower initiation stage induced flowering, increased the number of pods/plant and their by yield of soybean crop (Singh *et al.*

1987). The foliar spray of Naphthalene Acetic Acid (NAA) induces higher physiological efficiency including photosynthetic ability of plants. It leads to better growth and yield of several agronomic crops without substantial increase in the cost of production. NAA increases ethylene formation in plants, which facilitates the efficient translocation of photosynthetes from source to sink (Nebara *et al.* 2006). Hence, an attempt has been made to modify the growth of plant by use of appropriate growth regulators such as NAA and cycocel with valies doses and time of foliar application in mustard crop to increase productivity.

MATERIALS AND METHODS

The field experiment was carried out in winter *(rabi)* season during the year 2012-13 and 2013-14 at Rajaula Agriculture Farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalay, Chitrakoot, Satna (M.P.). The farm is situated under Baghelkhand region in Madhya Pradesh (25° 10' N latitude and 80° 52' E longitude and about 190-210 meter above mean sea level). This region comes under semi arid and subtropical climatic condition. The crop received a valies of 78.5 mm and 615 mm during Oct to Feb in 2012-13 and 2013-14, respectively. The soil was sandy loam with neutral pH (7.44), electrical conductivity (EC) 0.45 dSm^{-1}, low in organic carbon (0.35%) and available N (124.2 kg/ha) and medium in available P (14.3 kg/ha) and high in available K (321.5 kg/ha).

The treatment comprises of valies plant growth regulators *viz.* NAA @ 50 and 100 ppm at 20 and 40 DAS; CCC @ 100 ppm at 45, 60 and 75 DAS; NAA @ 50 and 100 ppm at 20 DAS + CCC @ 100 ppm at 60 DAS; NAA @ 50 and 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS along with one control. In all 12 treatments were tested in randomized block design (RBD) with 3 replications. Mustard variety 'Pusa Tarak' was sown on 15 and 12 October, 2013 and harvested on 6 and 5 February during subsequent respective year. An uniform dose of 60:40:20 kg N: P_2O_5: K_2O/ha were applied through urea, DAP and muriate of potash. The required quantities of seeds were treated uniformly with thiram 75% WP @ 3.0 g/kg seed. The sowing was done at 45 cm row spacing with seed rate of 5 kg/ha. Thinning was done at 20 DAS to keep the plant to plant spacing of 10 cm. At peak flowering stage, three plants of mustard were randomly dug up in each plot and washed the roots with the help of tap water, then measured root length and root spreading. In order to control weeds in all the plots, two hand weeding were done in both years. One spray of Delphos @ 0.75 kg/ha with 600 liter water were done as per the need for controlling of insect pests. Growth regulators were applied as per the treatments. Cost of production for all the treatment was worked out on the basis of the prevailing input and market price of the produce in 2013-14.

RESULTS AND DISCUSSION

Shoot and root growth

The plant growth parameters like plant height, leaves/plant and dry matter/plant were recorded significantly higher under the application of NAA @ 100 ppm at 20 DAS followed by NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS. NAA being of auxins group has the growth stimulatory effect which might have increased the growth parameters. The application of plant growth regulator provides better internal environment of growth to the plants and photosynthesis. Sumeriya *et al.* (2000b) also reported similar findings on mustard. Root length and root spread were not influenced significantly due to plant growth regulator treatments; but the highest values of all the parameters were noticed under NAA @ 100 ppm at 20 DAS and NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS. This increase might be due to the synergistic effects of these plant growth regulators on roots, which leads to more length and spreads of roots. These results are agreement with the findings of Vyas *et al.* (2009) in lentil.

Yield and yield attributes

Yield attributes *viz* siliqua/plant and 1000 seed weight were significantly enhanced with application of NAA @ 100 ppm at 20 DAS followed by NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS. This exhibited that application of plant growth regulator like NAA and CCC improved the metabolic activities of

Table 1. Effect of plant growth regulators on growth and yield attributes of mustard (Pooled data of 2 years)

Treatment	Plant height (cm) 60 DAS	Leaves/ plant 60 DAS	Dry Matter/ plant (g) 60 DAS	Root length (cm) 60 DAS	Root spreading (cm) 60 DAS	Siliqua/ plant	Seeds/ siliqua	1000 -seed weight (g)	Length of Siliqua (cm)
Control	123	21	2.72	16.8	8.8	238	12.3	4.81	5.1
NAA @ 50 ppm at 20 DAS	162	25	4.02	17.3	12.3	358	13.7	4.73	5.8
NAA @ 50 ppm at 40 DAS	151	25	4.03	18.2	13.2	364	13.3	4.82	5.5
NAA @ 100 ppm at 20 DAS	166	27	4.54	17.1	14.1	375	12.9	4.90	4.1
NAA @ 100 ppm at 40 DAS	152	21	4.33	17.8	11.9	364	13.0	4.89	5.6
CCC @ 100 ppm at 45 DAS	140	22	3.62	17.4	12.2	345	12.6	4.76	5.2
CCC @ 100 ppm at 60 DAS	138	22	3.73	17.4	13.3	361	12.2	4.65	5.3
CCC @ 100 ppm at 75 DAS	136	22	2.89	18.5	11.8	369	12.6	4.68	5.2
NAA @ 50 ppm at 20 DAS + CCC @ 100 ppm at 60 DAS	156	23	3.93	17.0	12.3	348	13.2	4.76	5.6
NAA @ 100 ppm at 20 DAS + CCC @ 100 ppm at 60 DAS	155	21	4.05	18.2	12.2	374	13.7	4.72	5.4
NAA @ 50 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS	157	25	4.18	17.6	12.3	364	13.1	4.76	5.3
NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS	165	26	4.37	18.6	13.4	379	13.7	4.90	5.8
SEm ±	5	1	0.28	0.4	1.1	34	0.41	0.05	0.50
CD (P=0.05)	14	3	0.83	NS	NS	100	NS	0.14	NS

Table 2. Effect of plant growth regulators on yield and economics of mustard (Pooled data of 2 years)

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net Returns (₹/ha)	B: C ratio
Control	1710	2227	17718	61507	43789	3.47
NAA @ 50 ppm at 20 DAS	1854	3254	18079	67325	49246	3.72
NAA @ 50 ppm at 40 DAS	2060	3183	18079	74474	56395	4.12
NAA @ 100 ppm at 20 DAS	2110	3384	18440	76375	57934	4.14
NAA @ 100 ppm at 40 DAS	1919	3367	18440	69675	51235	3.78
CCC @ 100 ppm at 45 DAS	1860	3329	17777	67583	49806	3.80
CCC @ 100 ppm at 60 DAS	1710	3149	17777	62199	44422	3.50
CCC @ 100 ppm at 75 DAS	1719	3339	17777	62677	44901	3.53
NAA @ 50 ppm at 20 DAS + CCC @ 100 ppm at 60 DAS	1793	3312	18588	65248	46661	3.51
NAA @ 100 ppm at 20 DAS+ CCC @ 100 ppm at 60 DAS	1919	3150	18949	69535	50587	3.67
NAA @ 50 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS	2019	3183	18588	73060	54473	3.93
NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS	2085	3339	18949	75601	56652	3.99
SEm±	63	258	-	2226	2226	0.12
CD (P=0.05)	185	752	-	6531	6531	0.36

plant which improves the yield attribute characters. Such increase was also ascribed due to greater growth parameter and better root system. Similar effects of NAA on yield attributes were also found by Kumar *et al.* (2003) in chickpea and Nebara *et al.* (2006) in fenugreek.

Seed and straw yield of mustard was exerted significantly higher under NAA @ 100 ppm at 20 DAS followed by NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS and NAA @ 50 ppm at 40 DAS. Application of NAA @ 100 ppm at 20 DAS, NAA @ 100 ppm at 40 DAS+CCC @ 100 ppm at 75 ppm, NAA @ 50 ppm at 40 DAS and NAA @ 100 ppm at 40 DAS +CCC @ 100 ppm at 75 DAS gave 23.4, 22.1, 20.4 more seed yield compared to control, respectively. This could be realised due to greater value of shoot and root growth and yield attributes. Positive effects of plant growth regulator NAA on productivity of mustard were also reported by Getachew *et al.* (2013) and Borjian and Arak (2013) in Brassica species. The effect of CCC was also confirmed by Arora *et al.* (2004) and Salunke *et al.* (2008) in their studies. Stover yield of mustard did not differ significantly but it was higher under NAA @ 100 ppm at 20 DAS, NAA @ 100 ppm at 40 DAS, NAA @ 100 ppm at 40 DAS+CCC @ 100 ppm at 75 DAS and CCC @ 100 ppm at 75 DAS. This could be due to better shoot and root growth. These results are confirmed with the findings of Khaliq *et al.* (2006) on mustard.

Economics

Application of growth regulator *viz.* NAA @ 100 ppm at 20 DAS gave the highest net returns followed by NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS and NAA @ 50 ppm at 40 DAS which were obtained significantly higher by 14145, 12863 and 12606/ha compared to control, respectively. This higher net return under plant growth regulator treatments was due to higher gross return as compared to lesser increase in cost of cultivation. Benefit: cost ratio was estimated highest under NAA @ 100 ppm at 20

DAS, NAA @ 50 ppm at 40 DAS and NAA @ 100 ppm at 40 DAS + CCC @ 100 ppm at 75 DAS as compared to other plant growth regulator treatments. Such increases were associated with higher values of gross returns compared to respective cost of cultivation. This is in line with findings of Sumeriya *et al.* (2000a).

CONCLUSION

It may be concluded that application of NAA @ 100 ppm at 20 DAS was the most appropriate treatment for mustard production and profitability in rainfed area of Chitrakoot region.

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Plant growth regulators priming enhances seed quality and enzymes activity in mungbean (*Vigna radiata* L.)

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Abstract

Field experiments were conducted at the research farm of Directorate of Seed Research, Mau to improve the germination, stand establishment, and growth of mungbean employing the seed priming techniques. Seeds of two mungbean varieties *viz:* Samrat and Pusa Vishal were sand primed with 50 ppm and 100 ppm solution of growth regulators *viz.* Gibberellic Acid (GA_3), Indoi Acetic Acid (IAA), Indol butyric acid (IBA) and Kinetin separately for 8 hours. Experiments were conducted in laboratory as well as in the cemented pots of 15 kg capacity. The results revealed that PGR priming showed significant enhancement in the seed quality parameters, growth, nitrate assimilatory enzymes and alpha amylase activity over unprimed control. Among treatments performance of GA_3 @ 100 ppm was superior over others in respect of seed germination, field emergence, seedling growth, vigour index 1 & 2, nitrate assimilatory enzymes including nitrate reductase and nitrite reductase and germination enzyme alpha amylase.

Key words: Mungbean, sand priming, plant growth regulator, seed quality, enzyme activity.

Pulses constitute an integral part of Indian agriculture because of its high nutritive values. Besides their higher dietetic value, they have a unique characteristic of maintaining and restoring soil fertility through biological nitrogen fixation and thus play a vital role in sustainable agriculture (Asthana, 1998). Pulses have a capacity to tolerate drought because of their deep root system (Rattanawongsa, N. 1993) and can be grown on marginal lands both as sole and intercrop. India is the largest producer and consumer of pulses in the world accounting for 33% of world 's area and 22% of world's production of pulses (Ref). In India, mungbean grown mainly in the states of Punjab, Haryana Uttar Pradesh, Madhya Pradesh, Bihar part of Rajasthan, Himanchal Pradesh and Jammu Kashmir in an area of 3.44 million ha with production of 1.40 million tons with a productivity of 406 kg/ha (Agro pedia, 2011). Mungbean matures in about 60-70 days after sowing and it is an excellent crop for rotation in different cropping systems. Besides Uttar Pradesh is low as compare to other regions of India w.r.t. mungbean production and there is the need to improve the seed quality, stand establishment and ultimately the crop production particularly in Uttar Pradesh. Priming is such technique of seed enhancement in which seeds are soaked in the solution of inorganic salt, plant growth regulators etc for specific period. The beneficial effect of priming with plant growth regulators have been reported by several workers in different crops *viz.* barley, maize, chickpea and mungbean (Panjabi *et al.*, 1982, Harris *et al.*, 2004; Suresh *et al.*, 2005 and Rashid *et al.* 2006). Keeping these facts in view, the present experiment was intended to understand the role of plant growth regulators (PGR) as priming agents on seed quality enhancement and enzymes activities involved in germination and nitrate assimilation during the germination of mungbean.

MATERIALS AND METHODS

The mungbean seeds were initially surface sterilized with 0.1 % $HgCl_2$ for five minutes. Those seeds were thoroughly washed after surface sterilization and sand priming was done as per treatments using two concentrations 50 ppm and 100 ppm solution of each plant growth regulators *viz.* Indole Butyric Acid (IBA), Indole Acetic Acid (IAA), Gibberellic Acid (GA_3) and Kinetin separately for 8 h period. After completing the period of priming, the seeds were taken out from the container and allowed for shade drying. Primed and unprimed seeds of each variety were sown in pots and germination paper by using between the paper methods with three replications according to ISTA rules (Anon., 1999). Final germination and root/shoot length were recorded after seven days of sowing and at same time the fresh seedlings were kept for drying in oven at 80°C for twenty four hour. Dried samples were weighed with an electronic balance and the vigour index 1 & 2 was calculated by following the method of Abdul-baki and Anderson (1973) as germination percent x seedling length and germination percent x seedling dry weight respectively.

Nitrate reductase activity was assayed following the method of Jaworski, 1971 in 250 mg fresh leaves using Phosphate buffer, Sodium nitrite, Propanol, Chlorophenical Sulphanilamide and N-1 napthyl ethylene diamine hydrochloride and O.D. was recorded on 540 nm. Standard curve was prepared with $NaNO_2$ solution. Whereas Nitrite reductase activity was estimated by the method of Ferari and Varner, 1971 placing 250 mg leaves sample in 4.5 ml assay medium containing Phosphate buffer Sodium nitrite and chlorophenical. Dimethylsulphoxide was added for reaction and finally Sulphanilamide and N-1 napthyl ethylene diamine hydrochloride was added to complete the reaction and develop colour. The O.D. was recorded on 540 nm using 10 ml aliquot.

Alpha amylase activity was assayed following the method of Bernfeld, P. 1955. Fresh sample (01 gm) was grinded with 10 ml $CaCl_2$ and incubated overnight at 4°C. Supernatants were used as an enzyme solution. Following reagents were prepared as per standard procedures

1. 0.1 M Sodium acetate buffer, pH 4.7
2. 1% Starch solution
3. Dinitro salicylic acid reagent
4. 40% Rochelle salt solution
5. Maltose solution

Enzyme assay

- Pepette out 1 ml of starch solution and 1 ml of properly diluted enzyme in test tube
- Incubate it at 27°C for 15 min.
- Stop the reaction by addition of 2 ml dinitrosalicylic agent
- Heat the solution in the boiling water bath for 5 min.
- While the tubes are warm, add 1 ml potassium sodium tartrate solution
- Then cool it in running water
- Make the volume to 10 ml by addition of 6 ml of water
- Read the absorbance at 560 nm.
- Terminate the reaction at zero time in the control tubes.
- Prepare the standard graph with 0-100 ug maltose.

All data obtained from fient experiment were analyzed as per standard statistical procedure.

RESULTS AND DISCUSSION

Mungbean seeds primed with different plant growth regulators including GA_3, IAA, IBA and Kinetin showed significant improvement in seed quality parameters over unprimed control. Enhancement in germination of both the varieties (Samrat and Pusa Vishal) was noticed when the seeds were primed with 50 and 100 ppm doses of each of GA_3, IAA, IBA and Kinetin. Among the PGR, priming with GA_3 @100 ppm showed maximum germination (80.5%) followed by IAA @ 50 ppm (78.1%) and IBA @ 50 ppm (77.8%) over control (65.1%). Percent improvement in germination was recorded 23.5, 19.8 and 19.4 with GA_3 100 ppm, IAA 50 ppm and IBA 50 ppm respectively comparing with control (Table 1).

Similarly field emergence was also followed the same trend and it was significantly higher with GA_3 100 ppm (66.6%), followed by IAA 50 ppm (54.9%) and IBA 50 ppm (55.3%). Improvement in field emergence due to PGR priming were 99.04, 64.19 and 59.24 with GA3 100 ppm, IAA 50 ppm and IBA 50 ppm respectively over control (Table 2).

Seedling length is the sum up of shoot length and root length and it was noted significantly higher with GA_3 100 ppm (43.5 %) over control (29.17) with the 49.43 percent improvement

Table 1. Response of plant growth regulators priming on germination (%) in mungbean.

Treatment	Germination (%)		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	65.90	64.40	65.15	
GA_3 50 ppm	72.88	77.58	75.23	15.47
GA_3 100 ppm	80.10	80.87	80.48	23.53
IAA 50 ppm	79.50	76.66	78.08	19.84
IAA 100 ppm	72.21	79.50	75.85	16.42
IBA 50 ppm	77.12	78.52	77.82	19.44
IBA 100 ppm	75.85	78.52	77.18	18.46
Kinetin 50 ppm	74.29	80.64	77.46	18.89
Kinetin 100 ppm	75.04	78.52	76.78	17.85
Varietal Mean	74.65	77.35		
	SE ±		CD (P=0.05)	
Variety (V)	0.41		0.84 **	
Treatment (T)	0.88		1.79 **	
V×T	1.24		2.53 **	
CV		2.04%		

Table 2. Response of plant growth regulators priming on field emergence in mungbean.

Treatment	Field emergence (%)		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	33.49	33.36	33.49	
GA_3 50 ppm	46.66	46.66	46.66	39.32
GA_3 100 ppm	60.00	73.33	66.66	99.04
IAA 50 ppm	43.33	66.66	54.99	64.19
IAA 100 ppm	50.43	46.66	48.33	44.31
IBA 50 ppm	43.33	63.33	53.33	59.24
IBA 100 ppm	43.33	63.33	53.33	59.24
Kinetin 50 ppm	50.00	43.66	46.83	39.83
Kinetin 100 ppm	40.00	60.00	50.00	49.29
Varietal Mean	45.61	55.22		
	SE ±		CD (P=0.05)	
Variety (V)	0.38		0.56**	
Treatment (T)	0.82		1.19**	
V×T	1.16		1.68**	
CV		2.69%		

(Table 3). The response of IAA 100 ppm was also remarkable (36.16%) and it was followed by GA_3 50 ppm (34.79%). Variety Samrat showed significantly higher seedling length over P.Vishal (Table 3). Interaction V × T was significant and noted highest seedling length with GA_3 100 ppm. Similarly seedling dry weight is the actual gain in growth and it was increased maximum (65.6%) with GA_3 100 ppm followed by GA_3 50 ppm (43.92%), Kinetin 50 ppm (43.68%) and IAA 100 ppm (43.6%) over unprimed control. Variety P.Vishal Showed significantly higher seedling dry weight over Samrat. Interaction of V × T was significant and it was noted highest with GA_3

Table 3. Response of plant growth regulators priming on seedling length in mungbean.

Treatment	Seedling length		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	28.90	29.45	29.17	
GA_3 50 ppm	39.16	39.49	39.32	34.7
GA_3 100 ppm	44.09	43.09	43.59	49.4
IAA 50 ppm	37.15	39.00	38.07	30.5
IAA 100 ppm	42.84	36.61	39.72	36.1
IBA 50 ppm	34.62	37.01	35.81	22.8
IBA 100 ppm	35.05	34.38	34.71	18.9
Kinetin 50 ppm	36.67	38.06	37.36	28.0
Kinetin 100 ppm	37.60	37.81	37.70	29.2
Varietal Mean	37.34	37.21		
	SE ±		CD (P=0.05)	
Variety (V)	0.00842		0.017 **	
Treatment (T)	0.01786		0.036 **	
V×T	0.02526		0.051 **	
CV		0.08%		

Table 4. Response of plant growth regulators priming on seedling dry weight in mungbean.

Treatment	Seedling dry weight		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	12.90	12.29	12.59	
GA_3 50 ppm	17.30	18.95	18.12	43.9
GA_3 100 ppm	21.14	20.56	20.85	65.6
IAA 50 ppm	16.29	17.96	17.12	35.9
IAA 100 ppm	20.44	15.72	18.08	43.6
IBA 50 ppm	14.65	16.78	15.71	24.7
IBA 100 ppm	16.80	15.93	16.36	29.9
Kinetin 50 ppm	16.91	19.28	18.09	43.6
Kinetin 100 ppm	17.36	17.59	17.47	38.7
Varietal Mean	17.08	17.22		
	SE ±		CD (P=0.05)	
Variety (V)	0.005		0.010 **	
Treatment (T)	0.011		0.023 **	
V×T	0.016		0.32**	
CV		CV = 0.11%		

100 ppm in samrat (Table 4). Observed enhancement in seed quality parameters might be the result of osmo-priming with growth regulators which imbibed the seeds and initiate the early stages of germination being osmo-lite and key hormones for germination. As a result maximum enhance-ment in vigour Index I & II was noted with GA_3 100 ppm priming treatment followed by IAA 100 ppm (Vigour Index I) (Table 5) and Kinetin 50 ppm (Vigour Index II) (Table 6) due to the fact that the process of cell division and cell enlargement was induced through these plant growth regulators priming.

Activities of nitrate assimilation enzymes including nitrate & nitrite reductase initiated immediately after onset of germination since they are reducing nitrate nitrogen to the available forms to the germinating seedlings and they were also influenced maximum by GA_3 100 ppm priming followed by IAA 100ppm (in case of nitrate reductase) (Table 7) and IAA 50 ppm (in case of nitrite reductase).Variety P.Vishal showed higher NR activity where as Samrat showed higher NIR activity (Table 8). Alpha amylase is the key enzyme of germination process and it was very much enhanced with PGR priming. The maximum enhancement was noted with GA_3 100 ppm followed by IAA 50 ppm and Kinetin 100 ppm (Table 9).Varieties did not show the significant variation in alpha amylase activity. Plant growth regulators evaluated have shown the positive effects on the enzymes activities might be due their

Table 5. Response of plant growth regulators priming on vigour index I in mungbean.

Treatment	Vigour Index I		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	2368.9	2444.9	2406.9	
GA_3 50 ppm	3250.5	3278.2	3264.3	35.6
GA_3 100 ppm	3660.0	3577.0	3618.5	50.3
IAA 50 ppm	3083.7	3237.2	3160.4	31.3
IAA 100 ppm	3556.8	3029.1	3293.0	36.8
IBA 50 ppm	2874.0	3072.3	2973.1	23.5
IBA 100 ppm	2909.7	2853.5	2881.6	19.7
Kinetin 50 ppm	3043.3	3159.2	3101.5	28.8
Kinetin 100 ppm	3121.1	3138.5	3129.7	30.0
Varietal Mean	3096.5	3087.8		

Table 6. Response of plant growth regulators priming on vigour index II in mungbean.

Treatment	Vigour Index II		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	1071.1	1020.0	1045.6	
GA_3 50 ppm	1435.9	1572.8	1504.3	43.8
GA_3 100 ppm	1754.6	1706.7	1730.6	65.5
IAA 50 ppm	1352.3	1490.9	1421.6	35.9
IAA 100 ppm	1696.5	1305.3	1500.9	43.5
IBA 50 ppm	1216.2	1393.0	1304.6	24.7
IBA 100 ppm	1394.9	1322.7	1358.8	29.9
Kinetin 50 ppm	1404.0	1600.7	1502.4	43.6
Kinetin 100 ppm	1441.3	1460.2	1450.7	38.7
Varietal Mean	1418.5	1430.3		

Table 7. Response of plant growth regulators priming on nitrate reductase activity in mungbean.

Treatment	Nitrate reductase activity (n mole g^{-1}f.w.h^{-1})		Treatment mean	% increase over control
	Samrat	P. Vishal		
Control	75.16	73.67	74.41	
GA_3 50 ppm	108.02	107.02	107.5	44.4
GA_3 100 ppm	127.68	120.34	124.0	74.4
IAA 50 ppm	89.85	100.30	95.07	27.7
IAA 100 ppm	117.35	111.38	114.36	53.6
IBA 50 ppm	81.51	87.11	84.31	13.3
IBA 100 ppm	79.15	79.52	79.335	6.6
Kinetin 50 ppm	85.24	92.46	88.85	19.4
Kinetin 100 ppm	86.61	95.70	91.155	22.4
Varietal Mean	94.50	96.38		
	SE ±		CD (P=0.05)	
Variety (V)	0.072		0.147 **	
Treatment (T)	0.153		0.312**	
V×T	0.217		0.442**	
CV		0.27%		

Table 8. Response of plant growth regulators priming on nitrite reductase activity in mungbean.

Treatment	Nitrite reductase activity (n mole g^{-1}f.w.h^{-1})		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	27.89	27.89	27.89	
GA_3 50 ppm	82.20	54.31	68.25	44.7
GA_3 100 ppm	104.22	54.31	79.26	84.1
IAA 50 ppm	52.84	49.51	51.17	83.4
IAA 100 ppm	45.50	36.70	41.01	47.3
IBA 50 ppm	41.10	42.57	41.83	49.9
IBA 100 ppm	55.78	32.29	44.03	57.8
Kinetin 50 ppm	45.50	45.50	45.5	63.1
Kinetin 100 ppm	36.70	36.70	36.7	31.5
Varietal Mean	54.63	42.19		
	SE ±		CD (P=0.05)	
Variety (V)	0.712		1.447	
Treatment (T)	1.510		3.071	
V×T	2.136		4.343	
CV	5.43%			

involvement in activation process induced through priming.

Conclusively, priming with GA_3 @100ppm performed better than rest of the priming treatments in respect of all the characters studied. Improvement in growth parameters might be the result of exogenous application of plant growth regulators through seed priming which could enhanced the seed quality parameters during seedling stage by enhancing the process of cell enlargement, cell division and

Table 9. Response of plant growth regulators priming on alpha amylase in mungbean.

Treatment	Alpha-amylase activity (mg. of maltose released/ml)		Treatment Mean	% increase over control
	Samrat	P. Vishal		
Control	1.10	1.15	1.13	
GA_3 50 ppm	1.12	1.16	1.14	10.1
GA_3 100 ppm	1.63	1.24	1.44	12.7
IAA 50 ppm	1.21	1.20	1.20	10.6
IAA 100 ppm	1.23	1.10	1.16	10.3
IBA 50 ppm	0.91	1.13	1.02	9.0
IBA 100 ppm	1.11	1.21	1.16	10.2
Kinetin 50 ppm	1.12	1.19	1.15	10.2
Kinetin 100 ppm	1.20	1.19	1.19	10.5
Varietal Mean	1.185	1.178		
		SE ±	CD	
Variety (V)		0.028	NS	
Treatment (T)		0.061	0.012**	
V×T		0.086	0.175**	
CV	8.91%			

activitation of several enzymes involved in germination process and growth of newly emerged seedlings. These results are also in harmony to some extent with the findings of Patel and Saxena 1994, Iqbal & Ashraf, 2007 and Perveen *et al.*, 2010 in wheat, Panjabi *et al.* 1982 in barley, Harris *et al.* 2004 in maize, rice and chickpea, Rashid *et al.* 2004 and Tiwari *et al.* 2013 in mungbean, Suresh and Janagoudar, 2005 in chickpea and Rashid *et al.* 2006 in barley. This technology may be adopted to improve the seed quality of pulses especially mungbean.

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Soil and plant based precision N management in *rabi* maize (*Zea mays* L.) in north-Indian alluvial plains

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ABSTRACT

A 2-year field experiment was conducted during 2010-11 and 2011-12 to determine the effect of soil and plant based precision nitrogen (N) application on growth, productivity, profitability and nitrogen-use efficiency of *rabi* maize (var. HQPM 5). The treatments of the experiment included, control (no-N), 60, 120 and 180 kg N ha^{-1}, soil based N (SBN), and plant based N (PBN) application, set in a three times replicated randomized complete block design (RCBD). N was applied in three splits, except in PBN supply where only15 kg N ha^{-1} was applied as basal and topdressing of 25-30 kg N ha^{-1} was done each time the SPAD values dropped to $\leq$ 37 till silking. The quantity of N for SBN was decided using soil test crop response (STCR) model. On an average, PBN application resulted in a grain yield of 6.88 t ha^{-1} that was almost equal to the yields obtained under 180 kg N ha^{-1} and SBN application with additional advantage of saving of 30 and 55 kg N ha^{-1}, respectively. These three treatments recorded significantly higher yields compared to lower rates of N application. Partial factor productivity, net returns and B: C ratio were also highest under PBN application. The agronomic efficiency was highest with 60 kg N ha^{-1} (24.8 kg grain per kg N) closely followed by PBN supply (24.2 kg grain per kg N), and lowest with SBN application (17 kg grain per kg N). Hence, it is concluded that plant based (SPAD value $\leq$ 37) scheduling of N has merit over the other approaches and N rates, and may be adopted in *rabi* maize.

Key words: Agronomic efficiency, factor productivity, precision nitrogen, *rabi* maize, chlorophyll meter

In India maize (*Zea mays* L.) contributes nearly 9% to the national food grain production and constitutes a quality feed for poultry and animals. Moreover, it serves as a basic raw material for the industry for production of starch for textile, pharmaceutical, cosmetic industries, high quality corn oil, protein, alcoholic beverages, food sweeteners, *etc.* It is used as an ingredient in more than 3000 products (Kumar *et al.*, 2013). With dramatic increase of maize demand in developing world, including India the current trend of maize production appears unable to keep pace with demand.

In the country, the area of maize is sticking to around 6-7 million hectare (m ha) since last three decades, and the trend of genetic gain in favourable environment seems unable to meet the fast growing demand of maize in the country (Yadav *et al.*, 2015). Maize is predominately a *kharif* season crop, but in past few years *rabi* maize has gained a significant place in total maize production in India. In 2013-14 *rabi* maize was grown on 1.75 mha with a production of 7.1 million tonnes (mt) and an average productivity of 4.1 t ha^{-1} (DACNET, 2014). Cultivation of maize in winter season started in mid 60s in some pockets. Yield obtained during this season is invariably higher (>6 t ha^{-1}) than the *kharif* season yield (2-2.5 t ha^{-1}) due to long duration of growth and least infestation of pests and diseases (Singh *et al.*, 2012). In absence of any major environmental impediments in *rabi*, the desired field operations can be planned and executed at the most desired time. Moreover, the various environmental factors, including absence of any major disease and insect-pest in this season, helps in realizing better profits from every additional unit of monetary inputs. In India, maize crop has been reported to respond to applied N upto a higher limit of 120-200 kg N ha^{-1}.

Maize crop, being a nutrient exhaustive crop requires a heavy supply of nitrogenous fertilizers, which causes a major concern and challenge to the producers because nitrogenous fertilizers are highly susceptible to losses due to leaching and volatilization and also increases the chance of ground water contamination and global warming. As a potential solution to such problems, could be a relatively new and mostly technology driven approach of precision nitrogen manage-ment involving chlorophyll meter may be followed (Dass *et al.*, 2014; 2015). A few researchers have used the SPAD meter in predicting chlorophyll content or N status of some crops including corn *(Zea mays)* (Schmidt *et al.*, 2009), rice *(Oryza sativa)* (Islam *et al.*, 2009; Cabangon *et al.*, 2011), cotton *(Gossypium sp.)* (Feibo *et al.*, 1998), and dry land winter wheat *(Triticum aestivum)* (Burling *et al.*, 2011) only in the last few years. However, no research regarding chlorophyll meter based N management in *rabi* maize is available. Hence, the current study was carried out to determine the effect of soil and plant based precision nitrogen (N) applications on growth, productivity, profitability, and agronomic efficiency of N (AEN) and factor productivity of N (FPN) in *rabi* maize.

MATERIALS AND METHODS

A field experiment was conducted during 2010-11 and 2011-12 to determine the effect of soil and plant based precision nitrogen (N) application on *rabi* maize (var. HQPM 5). The treatments of the experiment included, control (no-N), 60, 120 and 180 kg N ha^{-1}, soil based N (SBN), and plant based N (PBN) application, set in a three times replicated randomized complete block design (RCBD). N was applied in three splits, except in PBN supply where 15 kg N ha^{-1} was applied as basal and topdressing of 25-30 kg N ha^{-1} was done each time the SPAD values dropped to ≤ 37 till silking. In all, there were 6-split applications including basal dose, amounting to a total of 150 kg N ha^{-1} in PBN treatment. The quantity of N for SBN was decided using soil test crop response (STCR) model. Except in plant based supply, N was applied in three splits. However, entire amount of P (26.4 P ha^{-1}) and K (33.2 kg K ha^{-1}) was applied at the time of sowing. During crop period, rainfall of 65.7 mm occurred in 2010-11 and 43 mm in 2011-12. The crop required seven irrigations in 2010-11 and eight irrigations in 2011-12. Above and below ground growth and yield data were recorded using standard procedures. Economics of treatments was worked out using input costs and value of output prevailing during the study years.

Agronomic efficiency and factor productivity were computed using the following expressions :

- Agronomic efficiency (AE) (kg kg^{-1}) = (Yield at N_x–yield at N_0)/Applied N at N_x.
- Factor productivity of N (FPN) (kg kg^{-1}) = Grain yield (kg ha^{-1})/Quantity of N applied

The data were analyzed by using the 'Analysis of Variance Technique' as applicable to a Randomized Complete Block Design as per the procedures described by Rangaswamy (2006). Analysis of variance was carried out for the two-year period, considering year as a random effect. The significance of difference among different treatments was tested using F-test. Least significant difference (LSD) values were calculated for the parameters that exhibited significant difference. The treatment means were compared at 5% level of significance.

RESULTS AND DISCUSSION

Regular supply of N synchronised with maize crop demand under PBN application resulted in the tallest plants that were, however, statistically equal in height to the plants resulting from the application of 180 kg N ha^{-1} and SBN application (205 kg ha^{-1}). Plant height did not differ much

Table 1. Effect of soil and plant based precision N supply on growth characteristics of *rabi* maize

Nitrogen application rate (kg ha^{-1}) and approach	Plant height (cm)		Dry matter production (g plant^{-1})		Leaf area index		Dry root weight (g plant^{-1})	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
0	142.4	137.7	33.3	29.8	2.56	2.27	11.1	9.5
60	171.5	166.8	62.6	56.5	3.54	3.28	17.5	15.7
120	184.9	181.0	85.4	79.2	4.23	3.86	21.8	19.9
180	192.1	189.4	101.7	91.7	4.70	4.27	24.9	21.8
205 (SB)	190.0	190.2	99.5	92.5	4.59	4.31	25.1	23.2
150 (PB)	192.3	191.3	98.0	93.2	4.53	4.42	22.9	22.8
S. Em±	2.69	2.5	5.1	4.1	0.12	0.11	0.96	1.39
CD (P=0.05)	8.46	7.9	16.9	12.7	0.39	0.34	3.01	4.34

Note : SB: soil based; PB: plant based

Table 2. Effect of soil and plant based precision N supply on yields, harvest index and economics of *rabi* maize.

Nitrogen application rate (kg ha^{-1}) and approach	Grain yield (t ha^{-1})		Stover yield (t ha^{-1})		HI (%)		Net returns (Rs. ha^{-1})		B:C ratio	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
0	3.38	2.90	8.2	7.19	29.4	28.8	10,425	12,991	0.37	0.47
60	4.89	4.36	11.4	10.12	30.0	30.1	25,849	31,458	0.89	1.09
120	6.13	5.31	13.5	11.55	31.3	31.5	38,423	43,028	1.29	1.45
180	7.17	6.21	14.2	12.52	33.5	33.1	48,278	53,704	1.58	1.76
205 (SB)	6.93	6.32	14.1	12.68	33.0	33.3	45,551	54,845	1.47	1.78
150 (PB)	7.09	6.45	13.8	12.73	33.9	33.7	47,642	57,150	1.58	1.90
S. Em±	0.160	0.15	0.36	0.34	1.03	1.02	1,680	1,384	0.056	0.049
CD (P=0.05)	0.504	0.34	1.13	1.06	2.29	2.26	5,277	4,348	0.176	0.153

Note : SB: soil based; PB: plant based

Table 3. Effect of soil and plant based precision N supply on agronomic efficiency and partial factor productivity of *rabi* maize

Nitrogen application rate (kg ha^{-1}) and approach	Agronomic efficiency (kg grain per kg N)		Partial factor productivity (kg grain per kg N)	
	2010-11	2011-12	2010-11	2011-12
0	-	-		
60	25.2	24.4	81.5	73.6
120	22.9	20.0	51.1	44.9
180	21.1	18.4	39.8	34.4
205 (SB)	17.3	16.7	46.2	42.0
150 (PB)	24.7	23.7	34.6	31.4
S. Em±	1.32	1.51	1.69	1.94
CD (P=0.05)	4.31	4.93	5.52	4.58

Note : SB: soil based; PB: plant based between 2-study years for these three treatments. But under no-N and lower doses of N-application, plants were shorter during second year of study. Dry matter accumulation at maturity and leaf area index at taseling stage were significantly higher in treatments involving 180 kg N ha^{-1}, SBN and PBN application compared to lower doses of N and control. Between two study years, the 2010-11 supported higher dry matter production and leaf area index than 2011-12. Dry root weight increased significantly upto 180 kg N ha^{-1} during 2010-11 and 120 kg ha^{-1} in 2011-12. The highest DRW was recorded with SBN application, which declined marginally under plant based N additions as N was available in the upper surface soil layers regularly.

The root system plays predominant roles in nutrient uptake for plant growth and yield formation (Peng *et al.*, 2010). Better shoot and root growth under PBN led to higher grain and straw yields and net return from *rabi* maize. On an average, PBN application resulted in a grain yield of 6.88 t ha^{-1} that was almost equal to the yields obtained under 180 kg N ha^{-1} and SBN application with additional advantage of saving of 30 and 55 kg N ha^{-1}, respectively. These three treatments recorded significantly higher yields compared to lower rates of N-application. Higher grain yield with considerably lesser N-applications under PNB compared to SBN could be due to optimal N-supply through small but repeated N top-dressing throughout the crop growth period and reductions in N-losses by various means. N-saving in chlorophyll meter based precise N-application under PBN was substantial in this study. These N-savings in maize are comparable with those in rice crop, where chlorophyll meter based N-application reduced N-requirement by 12.5 to 25%, with no loss in yield (Singh *et al.*, 2002). Further, in rice, real time N-management involving SPAD 36 with 35 and 25 kg N ha^{-1} top-dressing could save N-fertilizer by 20 to 35% compared to one fixed time N-management without reducing grain yield (Ghosh *et al.*, 2013).

It is generally believed and also scientifically proved that N-deficiency stimulates early root growth, but this stimulatory effect lasts only for a short period and root growth starts declining when maize plants are still in the rapid vegetative growth stage with high N uptake activity (Peng *et al.*, 2012), due to early mortality of the early-initiated nodal roots and growth suppression of the later-initiated nodal roots. As root growth is closely associated with assimilate supply from the shoot (Ogawa *et al.*, 2005), the stimulated root growth in the early growth stage under N-stress is attained at the cost of reduced shoot growth (Marschner, 2011), that in turn, leads to insufficient carbon supply for continuous growth of early-initiated nodal roots and rapid elongation of later-initiated nodal roots and consequent shoot growth and yield. Whereas under adequate N supply (150-205 kg N ha^{-1}) in various splits, overall root growth and consequently growth and yield of maize are higher.

Partial factor productivity of N (PFPN), net returns and B:C ratio, were also the highest under PBN application due to higher yield and lower use of N. The agronomic efficiency (AEN) was, however, highest with 60 kg N ha^{-1} (24.8 kg grain per kg N) closely followed by PBN supply (24.2 kg grain per kg N), and the lowest with SBN application (17 kg grain per kg N). Improved N-supply in SPAD based real time N-management was primarily responsible for increased NUE and high rice grain yield (Peng *et al.*, 1996). Balasubramanian *et al.* (2000) also reported that AEN and PFPN were higher in SPAD based N management. Further, Ghosh *et al.* (2013) endorsed that agronomic N-use efficiency can be increased at high yield level using SPAD meter based N management.

From the results of this study, it is concluded that plant based (SPAD Value $\leq$ 37) precision N scheduling has merit in terms of root growth, shoot growth, yield, profitability and N-use efficiency, over the other approaches and N rates, and hence may be adopted in *rabi* maize.

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Impact of water management practices on productivity of soybean + maize intercropping system in Chambal command

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ABSTRACT

On-farm trials of soybean + maize intercropping system with improved water management practices were conducted during *Kharif* season from 2011 to 2014 at farmer's field of Left and Right main canal of Chambal command under Operational Research Programme (ORP) operated by Agricultural Research Station, Kota. The main objective was to evaluate impact of Soybean + Maize intercropping system in the row ratio of 4:2 with improved water management practices for enhancing the productivity and economics of soybean crop. Two treatments were evaluated at 12 locations and comprised of Improved water management practices i.e. two irrigations, first at full branching and second at pod development stages by border strip (6 m x 50 m) method using 80 per cent cut off ratio in soybean + maize intercropping system were compared with farmer's practice i.e. flood irrigation method both in sole crop of soybean and maize at 12 locations. Results revealed that soybean + maize intercropping system with improved water management practices gave higher and sustainable soybean equivalent yield over the years compared to farmers practice. The mean soybean equivalent yield (1663 kgha^{-1}) with 1.10 LER was 9.2 percent higher as compared to farmers practice (1525 kgha^{-1}). Pooled sustainability of soybean equivalent yield reflects the higher sustainability yield index (0.808) and sustainability value index (0.802). Efficiency indices for water use, production efficiency and incremental benefit cost ratio were also found higher in test block over the control block.

Key words: Soybean equivalent yield, sustainability value index, sustainability yield index and water management practices.

Soybean is an important oilseed crop as a valuable source of oil and protein for human nutrition in the world. It is most important and widely grown *Kharif* crop of south eastern Rajasthan. It occupies an area of 10.6 lakh ha and has a productivity of 956 kgha^{-1} in Rajasthan (Annual Report 2013-14). Low productivity in Rajasthan is mainly due to occurrence of intermittent dry spells, erratic rainfall during the growing season, improper water management and other agronomic practices. To stabilize crop production and to provide insurance against aberrant weather situation, intercropping could be a viable agronomic means of risk minimizing, more profit and subsistence oriented, energy efficient and sustainable venture (Faroda *et al.*, 2007; Dass and Sudhishri, 2010). Soybean being a deep rooted crop offers good scope for intercropping of short duration maize crop. The success of intercropping system depends mainly on suitable population of component crops in proper row adjustment to minimize the intercrop competition. Declining availability of irrigation water, need of sustainability in crop production and increasing demand of food and oil can be achieved through adoption of intercropping of soybean+ maize with improved water management practices. Therefore, the present study was undertaken through on farm trials at farmers field under operational research programme to show the benefits of intercropping of soybean + maize with water management practices in terms of enhanced soybean equivalent yield and saving of irrigation water.

MATERIALS AND METHODS

On farm trials were conducted in Chambal command which lies between 25° and 26° North latitude and 75°-30' and 76°-6' East longitude in the south eastern part of Rajasthan comprising part of Kota, Bundi and Barana Districts. It comes under agro climatic zone V which is also known as humid south eastern plain of Rajasthan. Kota Barrage, situated in Kota city serves the main canal system of Chambal command, from here the two main canals - right and left takes off. In absence of canal water, irrigation was given by the tube well *etc.*

The soils of the Chambal command belong to the order vertisols and inceptisols, mainly comprised of Chambal series (62%) and Kota variant (23%). The bulk density, pH and cation exchange capacity of demonstrated fields varied between 1.30-1.60 Mgm^{-3}, 7.80-8.45 and 30-40 Cm^{-1}/kg, respectively.

The soils have a very low water intake rate approximately 0.25 $cmhr^{-1}$ on surface where as almost impermeable at 1.2 to 1.5 m depth. The potential moisture retention capacity was almost 120 mm of water in 1 m depth. The soils of the experimental sites were medium in organic carbon (0.05 ± 0.08 %) and low in available nitrogen (275 ± 8 kg/ha) but are low to medium in available P_2O_5 (24.2 ± 0.6 $kgha^{-1}$) and medium to high in available K_2O (290 ± 8 $kgha^{-1}$).

The field trials were carried out from 2011 to 2014 during *kharif* season, at farmer's field under Operational Research Programme (ORP) of AICRP on Water Management to show economic feasibility and sustainability of soybean + maize intercropping system in the row ratio of 4:2 with improved water management practices. Each year twelve demonstrations were conducted, six each at tail reach of left main canal and right main canal system of Chambal command, respectively.

Improved water management practices *i.e.* two irrigation, one each at flowering and pod development stage with 6cm depth, by border strip method (6m × 50m at 80% cut off ratio) with recommended package of practices *viz.*, seed treatment, recommended dose of fertilizer (20:40:40:30 $Kgha^{-1}$, NPKS), weed management and seed rate (80 $Kgha^{-1}$) were used in test block during each year. Row to row spacing of soybean was 30cm. Maize was raised with row to row spacing of 60 cm using 25 kg seed/ha. Each demonstration was laid out in an area of 0.1 ha. For assessing impact of improved water management practices (IT), the adjoining field with similar area cultivated to sole soybean and maize crops by the farmer were considered as check plot (FP). Soybean equivalent yield with improved water management practices (IT) was compared with farmer's practice (FP) *i.e.* flooding method of irrigation with no control over the depth of irrigation (usually with irrigation depth of about 10 cm) in both the sole crops. For test plots measurement of water was done by velocity-area method at field level. The sowing in the demonstration plots was done during first fortnight of July every year except 2014 where, the sowing was done in third week of July due to delayed commencement of monsoon. The effective rainfall received during the crop growing period was 444.5, 485.1, 620.9 and 513.8 mm for the years of 2011, 2012, 2013 and 2014, respectively. Similarly, Evapotranspiration (ET) was 281, 343, 320 and 265 mm in the corresponding year. For comparison between treatments, the yields of crops were converted into soybean equivalent yield based on the prevailing market price. Production efficiency values in term of kg/ha/day were obtained by soybean equivalent yield of treatments divided by total duration of the crop in those treatments. Potential yield of soybean crop in humid south eastern plain zone of Rajasthan was 2500 kg/ha. Water use efficiency was calculated on the basis of ET using standard method explained by *Palaniappan* and *Sivaraman* (1996). Water expanse efficiency and water productivity were also analyzed using standard method (Singh and Kumar, 2011). The yield recorded from the demonstration blocks and farmer's practice blocks were analyzed for different parameters, using following formulae, suggested by Prasad *et al.* (1993).

(A) Extension Gap = Demonstration yield(Di) – Farmers practice yield (Fi)

(B) Technology Gap = Potential yield(Pi) – Demonstration yield(Di)

(C) Technology Index = (Pi – Di)/Pi × 100

Statistical analysis of the data for standard deviation and coefficient of variation was done as described by Panse and sukhatme, 1985. Sustainability indices (Sustainability yield index and sustainability value index) were work out using formula (Singh *et al.*, 1990).

$$\text{SYI} = \frac{\text{Estimated average yield} - \text{Standard deviation}}{\text{Maximum yield}}$$

$$\text{SVI} = \frac{\text{Estimated net return} - \text{Standard deviation}}{\text{Maximum net return}}$$

Water expanse efficiency =

$$\frac{\text{Economic crop yield (kg/ha)}}{\text{Water applied (ha.cm)}}$$

$$\text{Water use efficiency} = \frac{\text{Economic crop yield (kg/ha)}}{\text{Evapotranspiration (ha.cm)}}$$

$$\text{Water productivity} = \frac{\text{Net return (₹/ha)}}{\text{Water applied (m}^3\text{)}}$$

RESULTS AND DISCUSSION

Grain yield

Data pooled over the four years revealed that soybean equivalent yield (1663 kg/ha) increased by 9.2 per cent higher with the adoption of improved water management practices as compared to that of farmers practices (Table 2). The increase in the seed yield of demonstrations over farmer's practices ranged from 7.3 to 11.0 in different years. The higher soybean equivalent yield under demonstrations could be attributed to better utilization of resources under intercropping system. However, the variation in grain yield in different years might be due to the variation in the environmental conditions prevailed during that particular year. Joshi *et al.* (2004) have also observed that improved package of practices along with water management have shown positive effect on yield potentials of different crops. Similar findings have also been supported by Narolia *et al.*, 2013.

Water use

Efficiency indices for water use were estimated in terms of water productivity, water

Table 1. Effect of improved water management practices on sustainability of soybean + maize intercropping system at farmer's field.

Particulars		Year									
		2011		2012		2013		2014		Pooled	
		IT	FP	IT	FP	IT	FP	IT	FP	IT	FP
Soybean equivalent yield (kg/ha) range	Max	1810	1720	1795	1680	1550	1415	1730	1570	1721	1596
	Min	1750	1600	1710	1560	1495	1295	1510	1330	1616	1446
	Mean	1778	1657	1753	1630	1519	1369	1600	1442	1663	1525
Standard deviation		22.5	38.2	33.6	41.4	21.2	42.8	88.1	96.5	119	137
Coefficient of variation (%)		1.3	2.3	1.9	2.5	1.4	3.1	5.5	6.7	7.2	9.0
Net return range(₹/ha)	Max	47041	34160	50290	35900	46811	32195	57526	36810	58026	37310
	Min	45001	30800	47194	32300	44607	28235	48176	28890	45407	28235
	Mean	45964	32396	48754	34400	45563	30683	52001	32586	48670	32641
Standard deviation		765	1173	1224	1240	850	1413	3744	3183	1727	2700
Coefficient of variation (%)		1.7	3.6	2.5	3.6	1.9	4.6	7.2	9.8	3.5	8.2
Sustainability yield index		0.970	0.941	0.958	0.946	0.966	0.937	0.874	0.857	0.853	0.807
Sustainability value index		0.961	0.914	0.945	0.924	0.955	0.909	0.839	0.799	0.808	0.802

Max= Maximum soybean equivalent yield, Min= Minimum soybean equivalent yield IT=Improved water management practices, FP=Farmers practice expanse and water use efficiency. Mean data (Table 2) of four years indicated that higher water expanse efficiency (29.4 kg/ha-cm), water use efficiency (55.6 kg/ha-cm) and productivity of water (80.1 ₹ m^3 water) were observed in soybean + maize intercropping system with improved water management practices as compared to farmers practices. During the four years study, maximum water expanse and use efficiency were observed in 2011 which was due to higher seed yield and lesser quantities of water used in soybean + maize intercropping system. However, maximum water productivity obtained in 2014 which was 166 per cent higher as compared to farmers practices. These finding confirm the results of Dhar *et al.* (2011).

Gap Analysis

Extension gap is a parameter to know the yield difference between the demonstrated technology and farmer's practice where as technology gap a measures difference between potential yield and yield obtained under improved technology demonstration. Technology gap (TG) is of greater significance than other parameters as it indicates the constraints in implementation and drawbacks in our package of practices, these could be environmental or varietal. This also reflects the poor extension activities, which resulted in lesser adoption of improved water management technology and package of practices by the farmers. This gap can be lowered down by strengthening the extension activities and further research to improve the package of practices. Extension and technology gap ranged from 121 to 158 and 722 to 900 kgha^{-1} with the average of 138 and 837 kgha^{-1}, respectively. Better technology index (TI) of 28.9 % during the year 2011 could be due to introduction of soybean + maize intercropping system with improved water management practices, favorable climatic conditions, free from insect pest and disease incidence. However, poor technology index of 39.2 % during 2013 showed a poor performance of package of practices and demonstrated technology which was mainly due to the reasons of early withdrawal of monsoon and unfavorable climatic conditions coupled with higher incidence of pest and diseases. Similar results were reported by Narolia *et al.* (2013).

Economic analysis

Grain yield, cost of inputs and sale price of produce determine the economic returns and these vary from year to year with the variation in cost of input, labor charges and sale price of the produce. The year wise additional returns from soybean + maize intercropping system with improved technology demonstrations over farmer's practice varied from ₹ 3397ha^{-1} to ₹ 5330ha^{-1}. The mean additional cost of cultivation of all the demonstrations for four years was ₹ 725ha^{-1} (Table 3). This additional investment along with non-monitory management factors gave an additional mean return of ₹ 4392/ha. The higher sale price of soybean produce, in spite of low production and higher additional cost of input during 2014 gave highest additional returns under improved technology demonstrations over farmer's practice. The incremental benefit cost ratio (IBCR) on overall average basis was 6.2. The highest IBCR was

Table 2. Effect of improved water management practices on seed yield, gap analysis and efficiency indices for water use under soybean + maize intercropping system

Year	Yield (kg/ha)		WEE (kg/ha-cm)		WUE (kg/ha-cm)		WP (₹/m^3)					
	S. Equi. yield	Sole soybean	IT	FP	IT	FP	IT	FP	E. G (kg/ha)	T. G (kg/ha)	T.I (%)	LER
2011	1778 (*4148)	1657	35.2	30.4	63.3	59.0	76.6	32.4	121	722	28.9	1.07
2012	1753 (3507)	1630	32.2	27.9	51.1	47.5	81.3	34.4	123	747	29.9	1.08
2013	1519 (3341)	1369	22.3	19.0	47.5	42.8	75.9	30.7	150	981	39.2	1.11
2014	1600 (3500)	1442	27.9	23.5	60.4	54.4	86.7	32.6	158	900	36.0	1.12
Mean	1663 (3624)	1525	29.4	25.2	55.6	50.9	80.1	32.5	138	837	33.5	1.10

WEE=water expanse efficiency, WUE= water use efficiency, WP= Water productivity, LER= land equivalent ratio, EG= Extension gap; TG=Technology gap and TI= Technology index, * Maize yield

Table 3. Economic analysis of soybean + maize intercropping system at farmer's field

Year	Cost of cultivation (₹/ha)		Additional cost in IT	*Returns from grain yield (₹/ha)		Additional return in IT (₹/ha)	Effective gain (₹/ha)	IBCR	Production efficiency (kg/ha/day)	
	IT	FP		IT	FP				IT	FP
2011	14500	14000	500	49793	46396	3397	2897	6.8	18.5	17.3
2012	15100	14500	600	52590	48900	3690	3090	6.2	18.1	16.8
2013	15300	14500	800	50127	45177	4950	4150	6.2	15.2	13.7
2014	16000	15000	1000	56000	50470	5330	4530	5.5	17.4	15.7
Mean	15225	14500	725	52128	47736	4392	3667	6.2	17.3	15.9

*Returns from the soybean equivalent yield with mean sale price of ₹ 31.5kg^{-1} seed, IBCR= Incremental benefit cost ratio

observed in 2011 (6.8) this was due to comparatively higher grain yield, lesser cost of input and a good sale price. The results are in close agreement with the findings of Billore *et al.* (2009).

Sustainability

The pooled data of soybean equivalent yield (Table 1) showed higher values of standard deviation and coefficient of variation in case of farmer's practices as compared to improved water management practices. This might be due to more yield variations from farmer to farmer under farmer's practice and lesser with the adoption of improved water management practices. However, the values of sustainability yield index (SYI) and sustainability value index (SVI) were more under improved technology than farmer's practices. The mean values of SYI and SVI with improved water management practices ranged from 0.874 to 0.970 and 0.839 to 0.961 with the pooled values of 0.853 and 0.808, while the corresponding values under farmers practice were 0.857 to 0.946 and 0.799 to 0.924 with the pooled of 0.807and 0.802, respectively. This indicated that the soybean + maize intercropping system with improved technology are more sustainable as compared to farmer's practice. Similar results have also been reported by Billore *et al.* (2009) and Chary *et al.* (2014).

CONCLUSION

It can be concluded that soybean + maize intercropping (4:2) system with improved water management practices are more sustainable and profitable as compared to farmers practices in Chambal command area of Rajasthan.

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Intercropping efficiency of chickpea (*Cicer arietinum*) based intercropping system under rainfed condition of Bihar

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ABSTRACT

An experiment on Intercropping efficiency of chickpea (*Cicer arietinum*) based intercropping system under *rainfed* condition was carried out during *rabi*-seasons of 2009-10 and 2010-11 at Dholi farm of Rajendra Agricultural University, Pusa, (Samastipur), Bihar. Among the row ratio in intercropping systems, chickpea + linseed (6:1) expressed equal yield attributes and grain yield, and harvest index of chickpea than the chickpea + mustard in 6:1 and 6:2 ratio during both the years. The yield attributes, grain and straw yields, and harvest index of chickpea did not vary significantly due to fertilizer levels. The yield attributing characters of mustard and linseed were higher at 6:1 row ratio of intercropping than sole crops. The 6:2 row ratio of chickpea + mustard and chickpea + linseed recorded maximum grain and straw yields of mustard and linseed which were significantly higher over their 6:1 row ratio in both the years. Application of 100% and 75% RDF recorded similar grain yields of mustard and linseed and both turned significantly superior over 50% RDF in both the years. Chickpea + mustard irrespective of their row ratios recorded significant reduction in number of *Helicoverpa* larvae/10 plants, number of damaged pods/plant and pod damage percentage over chickpea + linseed and sole chickpea. Higher value of number of *Helicoverpa* larvae/10 plants, number of damaged pods/plant and pod damage percentage were recorded at 100% RDF than the lower levels of fertilizer but fails to exert significant effect on these indices except to pod damage percentage which were significantly more at 100% RDF than 50% RDF. Land equivalent ratio (LER) did not vary significantly among the row ratio in intercropping systems, only 6:1 row ratio of chickpea + mustard recorded significantly higher LER (1.15 and 1.16) over sole chickpea in both years. LER did not vary significantly among different fertilizer levels. Chickpea + mustard in 6:1 row ratio altogether recorded maximum chickpea equivalent yield (CEY) (2233 and 2501 kg ha^{-1}) and net return (Rs. 44828 ha^{-1}) however, B: C ratio (BCR) was higher under 6:2 row ratio of chickpea + mustard (2.10) which was at par with 6:1 row ratio of chickpea + mustard (2.08). Chickpea + mustard in both the row ratio recorded significantly higher CEY, net return and B:C ratio over chickpea + linseed in both the row ratio and sole chickpea. CEY, gross and net returns, BCR and LER did not varied significantly among the fertilizer levels.

Key words: Chickpea, fertilizer levels, Indian mustard, intercropping, linseed, row ratio, *rainfed.*

Chickpea (*Cicer arietinum* L.) is an important pulse crop of semi-arid tropics particularly rainfed ecology of India. In Bihar, chickpea is grown in an area of about 0.98 lakh ha producing 1.08 lakh tones grains with average productivity of 1100 kg ha^{-1}, mostly with minimum input (Anonymous, 2010-11). Chickpea play a key role in improving and sustaining soil productivity on account of biological nitrogen fixation and addition of considerable amount of organic matter. India has achieved self sufficiency in food grain production but lagging behind in pulse and oilseed production. Pulses account for 16% of the total cultivated land area in India but contributing 8% to the national food production (Pooniya *et al.* 2015). The poor productivity of pulses is attributed to cultivation of traditional varieties of pulse crop and sub-optional or no use of fertilizer. Chickpea is traditionally grown as a mixed crop with several crops like mustard, linseed, barley, spices etc without taking into consideration of planting geometry, space and fertilizer consequently crop suffer to a great extent and their yields are reduced (Choudhary and Suri, 2014). Plant population, spatial arrangement and fertilizer management in intercropping have important effect to balance the competition between the component crops and their productivity (Kumar *et al.* 2015).

Intercropping of oilseed and pulse crops is one of the ways to increase their production because intercropping is more advantageous than sole cropping of either of these crops (Kumar *et al.* 2015). Chickpea based intercropping systems are very popular particularly under rainfed conditions. The inter cropping proves more beneficial under such conditions. To achieve higher productivity and profitability spatial arrangement and fertilizer application in intercropping systems is essential. A lot of information is available on cereal + legume intercropping, but not on legume + oilseed intercropping system. The detail information of comparative performance of the crops, nutrient application, competition relations and sustainability of the system under rainfed situations of Bihar is lacking. Keeping above aspect in view, an experiment was conducted to find out the suitable intercrop with chickpea, their appropriate row arrangement and fertilizer levels to enhance productivity and profitability of the systems.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* seasons of 2009-10 and 2010-11 at Tirhut College of Agriculture, Dholi Farm of Rajendra Agricultural University, Pusa, (Samastipur), Bihar. The soil of experimental plot was low in organic carbon (0.47%) available nitrogen (174.3 kg ha^{-1}), medium in available phosphorus (23.6 kg ha^{-1}) and potassium (130.6 kg ha^{-1}) with pH 8.7. The treatments comprised of two intercropping systems, *viz.* chickpea + mustard and chickpea + linseed, two row arrangement *i.e.* 6:1 and 6:2 together with sole cropping of each crop and three fertilizer levels to intercrops *viz.* 50% RDF, 75% RDF and 100% RDF (60:40:40:20:: N:P:K:S, kg ha^{-1}). The experiment was laid out in randomized block design with three replications. Sole crop of chickpea, mustard and linseed were fertilized with recommended dose of fertilizers. The recommended dose of fertilizer (RDF) for chickpea was 20:40:20:20:: N:P:K:S kg ha^{-1} and 60:40:40:20:: N:P:K:S kg ha^{-1} for mustard and linseed. The entire quantity of fertilizers was side dressed at the time of sowing to base as well as component crops in sole as well as in intercropping systems. The chickpea varieties '*KPG-59*', mustard '*Rajendra Suflam*' and linseed 'Shekhar' were sown in rows 30 cm apart in 1st and 2nd year of experimentation respectively by using the seed rate of 75, 05 and 20 kg ha^{-1} to chickpea, mustard and linseed, respectively. The chickpea and linseed were harvested in April while mustard was harvested in March during both years. The plant to plant distance (10 cm) in sole and intercropping systems were maintained by thinning at 14 days after sowing (DAS). For comparison between the treatments, yields of crops were converted into chickpea equivalent yield (CEY) at prevailing market price.

Determination of inter cropping efficiency

Here efficiency of intercropping was judged by crop equivalent yield and land equivalent ratio.

Chickpea equivalent yield (CEY)

CEY was computed by converting yield of mustard and linseed into the yield of chickpea on the basis of prevailing market prices using following formula:

$$\text{CEY (kg/ha}^{-1}) = \frac{\text{Yield of intercrop (kg ha}^{-1}) \times \text{Price of inter crop (Rs ha}^{-1})}{\text{Price of base crop (Rs ha)}} + \text{Yield of base crop (kg ha}^{-1})$$

Land equivalent ratio (LER)

It was calculated as sum total of the ratios of yield of each component crop in an intercropping or a mixed cropping system its corresponding yield when grown as a sole crop, thus:

$$\text{LER} = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where,

Y_{ab} was the yield of chickpea in association with mustard/linseed

Y_{ba} was the yield of mustard/linseed in association with chickpea

Y_{aa} and Y_{bb} represent the pure stand of chickpea and mustard/linseed, respectively.

Harvest index (%)

Harvest index (%) was calculated as the ratio of economic yield (grain) and total biological yield multiplied by 100. Its value was expressed in percentage as :

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

(Excluding root mass)

System Production Effeciency

System Production Effeciency per day was calculated as the ratio of CEY and total crop duration in days (Kumar *et al.*, 2015).

$$\text{System Production Effeciency} = \frac{\text{CEY (kg ha}^{-1}\text{)}}{\text{Total crop duration (days)}}$$

RESULTS AND DISCUSSION

Yield attributes

Number of pods/plant, seeds/pod and test weight of chickpea remained unaffected due to row ratios of intercropping systems as well as sole chickpea in both the years except number of seeds/pods in first year (Table 1). Among the row ratios of intercropping systems, those indices were higher in 6:1 row ratio as compared to 6:2 row ratio. Number of siliquae/plant, number of seeds/siliqua and test weight of mustard did not vary significantly among the row ratios of chickpea + mustard intercropping system. However, number of siliquae/plant in second year and number of seeds/siliqua in both the years were significantly higher in 6:1 row ratio of chickpea + mustard as compared to sole mustard. In linseed number of capsules/plant in first year and seeds/capsule in second year were significantly higher in 6:1 row ratio than 6:2 row ratio of chickpea + linseed intercropping as well as sole linseed. Test weight of linseed remained unaffected at either the row ratio of intercropping as well as in sole linseed. Number of pods/plant, seeds/pod and test weight did not vary significantly at different fertility levels. The maximum number of siliquae/plant, seeds/siliqua in mustard and capsules/plant and seeds/capsule of linseed were recorded at 100% RDF which was significantly higher than 50% RDF in both the years. The test weight of both component and inter crop did not varied significantly at different fertility levels. This might be due to lesser intercrop competition, higher photosynthetic active radiation and latent heat available to the crops leading to higher production of photosynthates which together favorably influenced the yield attributing parameters. These finding are in line of Abraham *et al.* (2010).

Yield

Grain and straw yields of chickpea, mustard and linseed were highest in their respective sole crop as compared to their intercropping, on account of higher plant population in sole than intercroppings (Table 1). Among the intercropping systems, 6:1 row ratio of chickpea + linseed recorded maximum grain yield of chickpea which was significantly higher than 6:2 row ratio of chickpea + mustard in both the years and 6:2 row ratio of chickpea + linseed in second year. However, 6:2 row ratio of chickpea + linseed recorded the maximum straw yield in first year which was significantly higher than 6:1 row ratio under both the intercropping systems while in second year it did not vary significantly among the row ratios in both the intercropping systems. The increase in grain and straw yields was possibly due to better growth, increased number of pods/plant, seeds/pods and higher plant density. Grain and straw yield of mustard and linseed increased significantly with increase in fertility levels of intercrops up to 75% RDF. Further increase in fertility level failed to produce significant effect on grain and straw yields. The maximum grain and straw yield of mustard and linseed were recorded in sole stand which was significantly higher than both the row ratios of intercropping systems of these crops. Among the

Table 1. Yield attributes of chickpea, mustard and linseed as influenced by intercropping systems and fertility levels

Treatments	Number of pods, siliquae, capsules/plant						Number of seeds/pod or siliqua or capsule					
	Chickpea		Mustard		Linseed		Chickpea		Mustard		Linseed	
	I	II	I	II	I	II	I	II	I	II	I	II
Sole chickpea	39.3	47.3	-	-	-	-	2.3	2.6	-	-	-	-
Sole mustard	-	-	241.3	260.4	-	-	c	-	7.8	8.2	-	-
Sole linseed	-	-	-	-	27.3	38.3	-	-	-	-	4.7	5.4
Intercropping systems												
Chickpea + Mustard (6:1)	37.4	43.4	260.6	318.6	-	-	2.1	2.5	9.2	10.3	-	-
Chickpea + Mustard (6:2)	35.7	42.8	249.0	301.4	-	-	2.0	2.5	8.4	9.8	-	-
Chickpea + Linseed (6:1)	38.1	46.4	-	-	38.0	45.7	2.3	2.5	-	-	6.4	7.5
Chickpea + Linseed (6:2)	36.5	45.4	-	-	31.3	41.1	2.2	2.5	-	-	5.3	6.0
CD (P=0.05)	NS	NS	NS	NS	3.9	NS	0.2	NS	NS	NS	0.7	0.8
Sole vs. rest	NS	NS	NS	28.9	3.2	4.1	NS	NS	0.8	0.9	0.6	0.6
Fertility levels to inter crop												
50%RDF *	37.8	45.4	220.4	272.8	30.0	36.3	2.2	2.6	7.1	8.4	4.6	4.8
75%RDF	37.2	44.4	260.7	319.5	35.3	44.3	2.2	2.5	9.0	10.6	6.0	7.4
100%RDF	35.7	43.6	283.8	337.6	38.6	49.5	2.1	2.4	10.3	11.1	6.9	8.0
CD (P=0.05)	NS	NS	35.2	42.7	4.8	6.0	NS	NS	1.2	1.4	0.8	1.0

*Recommended dose of fertilizer

Table 2. Yield (kg/ha) and harvest index (%) of chickpea, mustard, linseed, as influenced by different intercropping systems and fertility levels

Treatments	Grain yield (kg ha^{-1})						(Straw yield (kg ha^{-1})					
	Chickpea		Mustard		Linseed		Chickpea		Mustard		Linseed	
	I	II	I	II	I	II	I	II	I	II	I	II
Sole chickpea	1904	2146	-	-	-	-	2914	3326	-	-	-	-
Sole mustard	-	-	1893	1936	-	-	-	-	4884	5073	-	-
Sole linseed	-	-	-	-	1295	1329	-	-	-	-	4754	4756
Intercropping systems												
Chickpea + Mustard (6:1)	1762	2002	421	446	-	-	2310	2677	1044	1116	-	-
Chickpea + Mustard (6:2)	1659	1821	500	560	-	-	2395	2714	1225	1378	-	-
Chickpea + Linseed (6:1)	1821	2017	-	-	205	236	2235	2723	-	-	729	811
Chickpea + Linseed (6:2)	1741	1890	-	-	246	288	2456	2562	-	-	849	955
CD (P=0.05)	103	114	53	58	26	30	138	NS	130	83	90	60
Sole vs. rest	134	149	91	95	59	62	183	208	233	135	215	120
Fertility levels to inter crop												
50%RDF *	1773	1981	395	424	196	202	2352	2671	1010	1089	703	702
75%RDF	1752	1938	463	515	233	275	2346	2668	1141	1293	822	939
100%RDF	1713	1878	523	569	248	307	2348	2668	1252	1358	841	1008
CD (P=0.05)	NS	NS	65	71	32	37	NS	NS	159	102	110	73

*Recommended dose of fertilizers

Table 2. **Incidence of pod borer (*Helicoverpa armigera*), cropping efficiency (system productivity per day, CEY and LER) and economics as influenced by different intercropping systems and fertility levels**

Treatments	No. of larvae/10 plant		No. of damage pods/plant		Pod damage (%)		System production/ efficiency (kg/ha/day)		CEY (kg ha^{-1})		LER		Pooled gross return (x 10^3 Rs/ha)	Pooled net return (x 10^3 Rs/ha)	Pooled B:C ratio
	I	II	I	II	I	II	I	II	I	II	I	II			
Sole chickpea	2.7	2.3	3.6	3.1	9.1	6.6	13.7	14.5	1904	2145	1.0	1.0	56.9	34.7	1.6
Sole mustard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sole linseed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Intercropping systems															
Chickpea + Mustard (6:1)	1.4	1.3	1.6	1.4	4.3	3.3	16.1	16.9	2233	2501	1.2	1.2	66.3	44.8	2.1
Chickpea + Mustard (6:2)	1.3	1.2	1.5	1.3	4.2	3.1	16.0	16.5	2218	2447	1.1	1.1	66.0	44.8	2.1
Chickpea + Linseed (6:1)	2.4	2.3	2.5	2.5	6.7	5.3	15.0	15.7	2084	2318	1.1	1.1	61.4	40.1	1.9
Chickpea + Linseed (6:2)	2.4	2.0	2.2	2.1	6.1	4.7	14.8	15.3	2055	2257	1.1	1.1	60.9	39.5	1.9
CD (P=0.05)	0.2	0.2	0.2	0.2	0.6	0.5	0.9	1.0	127	141	NS	NS	NS	3.7	0.2
Sole vs. rest	0.3	0.3	0.3	0.3	0.8	0.6	1.2	1.2	162	180	0.1	0.2	7.1	4.7	0.2
Fertility levels to inter crop															
50% RDF *	1.7	1.6	1.9	1.8	5.1	4.0	15.2	15.9	2119	2348	1.1	1.1	62.9	41.6	2.0
75% RDF	1.9	1.7	2.0	1.8	5.4	4.3	15.5	16.2	2160	2403	1.1	1.1	64.2	42.8	2.0
100% RDF	1.9	1.8	2.1	1.9	5.8	4.5	15.6	16.2	2164	2393	1.1	1.1	63.9	42.5	2.0
CD (P=0.05)	NS	NS	NS	NS	0.5	0.4	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Recommended dose of fertilizers

intercropping systems, 6:2 row ratio of chickpea + mustard and chickpea + linseed recorded the maximum yield of intercrops which was significantly higher than 6:1 row ratio of these crops in both the years. Harvest index of chickpea, mustard and linseed did not vary significantly under intercropping systems as well as in sole. Similarly the harvest index of intercrops *i.e* mustard and linseed also did not vary significantly at fertility levels. This might be due to increasing levels of fertilizers to intercrops increases photosynthetic rate and translocation of photosynthate to different plant parts particularly towards grains. (Abraham *et al.*, 2011).

Incidence of pod borer (Helicoverpa armigera) in chickpea

Insect pest are major bottle neck in realizing its potential yield of the crops. Pod borer *(Helicoverpa armigera)* is one of the major insect pests of chickpea. Massive application of pesticides not only leaves harmful residues in the food chain and bad effects on the environment but also cause development of resistance in insects to insecticides. Intercropping of chickpea with non-host plant had some suppressing effect on pod borer through the change in crop canopy which resulted in change of microclimate. In the present investigation data were gathered in respect of number of larvae/10 plants, number of damaged pods/plant and pod damage percentage (Table 3). Significantly lesser number of larvae/10 plants, number of damaged pods/plant and pod damage percentage were recorded due to intercropping of chickpea + mustard, irrespective of row arrangements, which followed in order by chickpea + linseed and sole chickpea. This might be due to change in crop canopy and resultant change in micro-climate which may hinder the adult pod borer moth to identify the crop and move freely in the field to lays their eggs in between the rows of intercrops. Similar results have been reported by Gupta *et al.* (2008).

Intercropping efficiency

Intercropping efficiencies in the present investigation is judged by system production efficiency (SPE) and chickpea equivalent yield (CEY). Maximum was recorded in 6:1 row ratio of chickpea + mustard which was at par with 6:2 row ratio of chickpea + mustard but was significantly higher over both the row ratios of chickpea + linseed and sole chickpea in both the years (Table 3). The higher SPE in this row ratio was as a result of increase in seed yield of component crop in intercropping systems with little effect on the yield of main crop chickpea equivalent yield among the different row ratios in intercropping systems. Maximum CEY was recorded in 6:1 row ratio of chickpea + mustard however, was at par with 6:2 row ratio of chickpea + mustard but was significantly higher over both the row ratios of chickpea + linseed and sole chickpea in both the years (Table 3). The higher CEY at this row ratio was as a result of increased seed yield of component crop in intercropping with little effect on the yield of main crop. There was little variation in CEY due to fertility levels. In first year, it was higher at 100% RDF whereas in second year, it was more at 75% RDF but the differences were not significant. Similar results were also obtained by Abraham *et al.* (2011).

Land equivalent ratio (LER)

LER varied accordingly in intercropping systems as compared to sole chickpea. However, it did not differ significantly among the intercropping systems. A perusal of mean data reveal that maximum LER recorded in chickpea + mustard intercropping under 6:1 row ratio, but the difference was non significant with sole chickpea during both the years of experimentation. Among the intercropping systems, highest LER was recorded under chickpea + mustard in 6:1 row ratio (Table 3). While it was lowest under chickpea + linseed in 6:2 row ratio in both the years of experimentation. Among the fertility levels, LER increased with increase in fertility levels up to 75% fertility level in both years.

Economics

The row ratios of intercropping system had no pronounced effect on pooled gross return but it showed significant variation when compared with sole chickpea. Both the row ratio of intercropping systems recorded higher net return and B:C ratio compared (BCR) to sole chickpea. Maximum gross return, net return and (BCR) were recorded in 6:1 row ratio of chickpea + mustard which was at par with 6:2 row ratio of the same intercropping and significantly higher over both the row ratio of chickpea + linseed and sole chickpea (Table 3). This might be due to more yield advantage in 6:1 and 6:2 row ratio of chickpea + mustard intercropping system which ultimately fetched maximum gross and net returns and BCR. These results are in accordance with those of Abraham *et al.* (2010), Fetilizer levels to intercrop had non significant effect on gross and net return and BCR, though the net return and BCR were slightly higher at 75% RDF. This might be due to higher cost incurred on fertilizers application at higher fertility level with no commensurate increase in the crop yield.

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Thermal requirement and phenological development of different grape varieties under South-Western Punjab

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ABSTRACT

A field experiment was conducted to work out relationship between heat unit requirement and phenophases of 15 grape varieties during the years (2008 and 2009) at Punjab Agricultural University, Regional Research Station, Bathinda (Punjab). All the phenological stages *i.e.*, bud burst, sprouting, panicle initiation and anthesis took less number of days, (during the year 2009), while the fruit set and fruit ripening was earlier during the year 2008. The varieties Madeliene Anguvine, Banquiabyad, Beauty Seedless and Perlette ripened about 30 to 60 days earlier than the late ripening varieties *viz.*, Arka Shyam and Arka Kanchan. For all the phenological stages, the grape varieties under study accumulated more heat units (mean value) during the year 2009 (1720.4 °C day) as compared to the year 2008 (2135.5 °C day). Early maturing varieties consumed lesser heat units for fruit ripening, as compared to late ripening varieties. In both the years, the average fruit yield was observed maximum in Perlette (31.57t/ha) followed by Cardinal (29.87t/ha) while the Ruby Red, Bharat Early and Delight were among the lowest fruit yielding varieties. The mean heat use efficiency was slightly higher (4.41 t/ha/°C) during the year 2008 as compared to year 2009 (3.44 t/ha/°C). A significant positive correlation was found between number of days for different phenological phases and cumulative heat units.

Key words: Grape varieties, heat-use efficiency, semi-arid environment, South-Western region, thermal requirement

In South-Western region of Punjab, area under grapes has been reducing since last decade as a result of fluctuations in temperature, erratic rainfall and short shelf life. Variation in weather parameters is considered major factors of inter-annual variability of plant growth and yield. All the crops are vulnerable to different temperature stresses during the crop season and differential response of temperature change to various crops has been noticed under different production environments (Kalra 2008). Out of all the cultivated plants, the grapevine is considered as one of the most responsive to its surrounding environment (Becker, 1984). Many factors other than temperature drive viticulture suitability (Jackson and Schuster, 2001), simple to complex indices of temperature are the most common measures used to assess what types of grapes can be grown in which climates (Jones *et al.* 2010).

The occurrence of different phenological events during growing season of any crop and the effect of temperature on plant growth can be inferred using accumulated heat units or growing degree days. Any change in optimum temperature during its vegetative or reproductive growth adversely affects the initiation and duration of different phenophases and finally yield of the fruit plants. The concept of heat units and heat use efficiency has been applied to correlate the phenological development of different crops to predict yield and physiological maturity (Swan *et al.* 1989; Singh *et al.* 2007). It is therefore essential to have the knowledge of exact duration of different phenophases in existing environment and their relation with yield determinants, for achieving high yields in grapes. Thus the present study was conducted to assess the performance of different grape varieties in terms of heat unit requirement, heat use efficiency and fruit yield.

MATERIALS AND METHODS

Fifteen varieties of grapes planted in 1996 at Regional Station, Bathinda were used as plant material for the study conducted during the year 2007-08 and 2008-09. One vine of each variety planted at 3 × 3 m apart trained on Bower System formed one replication. The treatment was replicated thrice in randomized block design.

The study area (Bathinda, 30°17' N ; 74°58'E, 211 m ASL) comes under agro-climatic zone V *i.e.*, semi-arid region of Punjab, India. June is the warmest month of the year, with mean daily maximum and minimum temperature of 41 °C and 26 °C, respectively. January is the coldest month of the year, with mean daily maximum and minimum temperature of 20 °C and 4 °C, respectively. The mean annual rainfall is about 424 mm, 80 percent of which is received during the South-Western monsoon season (First week of July to mid September) and remaining during the winter season. Besides it, strong winds coupled with dust storms prevail during the months of May and June. Frosty nights and chilled winds are most common during December and January.

The weather was taken from the agromet observatory installed at Regional Station, Bathinda. The heat units or growing degree days (GDD) were calculated using the following formula (Rai *et al.* 2002):

$$\text{GDD or Heat units} = T_{mean} - T_{base}$$

Where T_{mean} is the mean temperature and T_{base} is the base temperature below which fruit growth is arrested. The base temperature for grapes is taken as 10 °C (Brar *et al.* 1992). The observations on fruit yield were recorded from each vine and were converted into ton/hactare.

Heat use efficiency was worked out by dividing the yield with cumulative heat units.

$$\text{HUE} = \text{Yield/AGDD (t/ha/°C day)}$$

Different phenological stages *i.e.*, bud burst, sprouting, panicle initiation, anthesis, fruit set and fruit ripening (from February to end June) were recorded by observing the vines on every alternate day.

RESULTS AND DISCUSSION

The weather data of both the years are presented in Fig. 1. The maximum and minimum temperatures for the month of January and February were below the normal (ranging from -1.7 to -3.6°C) during the first year and above the normal during the second year and it were near to normal during April in both the years. The months of May and June were cooler in the first year as compared to the second year. A total of 223.2 mm and 35.9 mm of rainfall was received during the period from March- June in the first and second year respectively. Mean relative humidity during the years 2008 and 2009 is ranged from 47 to 67 and from 36-76 per cent respectively.

Phenology of grape varieties

Numbers of days taken to attain any phenological event varied across varieties during both the years (Table 1&2). All the phenological stages *i.e.*, bud burst, sprouting, panicle initiation and anthesis took less number of days during 2009, while the fruit set and fruit ripening was earlier in 2008. This may be due to the high temperature during the months of February in the second year which results in early bud burst followed by sprouting resulting in earlier panicle initiation and anthesis. The bud burst was initiated on 32th day and it was completed on 51st day. Likewise the sprouting was initiated on 34th day and was completed in 57th day during both the years. Perlette and Delight took minimum number of days for bud burst and sprouting. Panicle initiation was earliest in Delight (42 days) followed by Madeliene Anguvine while the maximum days (61) for panicle initiation were taken by Arka Shyam. The anthesis was earliest in Ruby Red (65 days) followed by Beauty

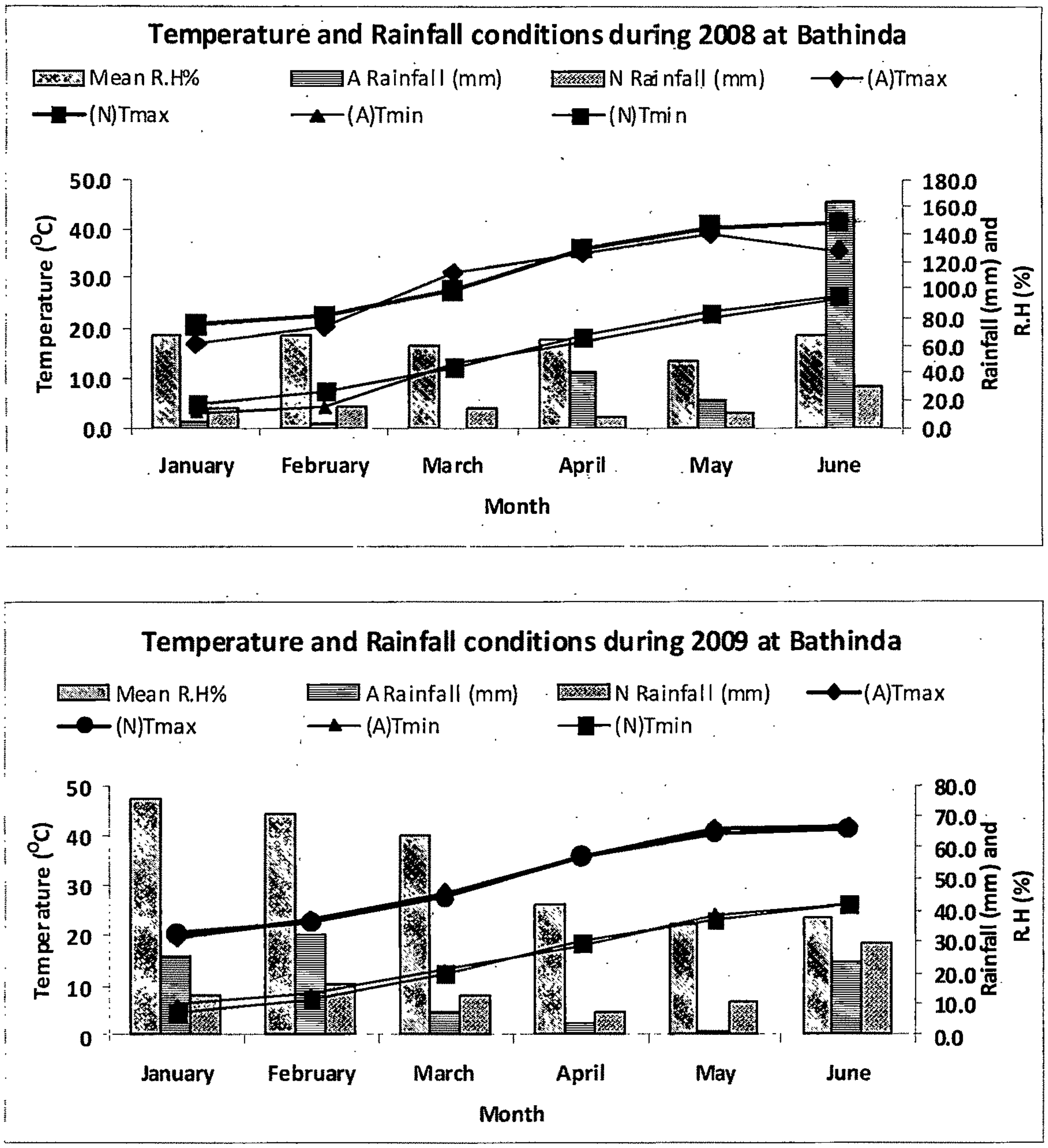

Fig. 1. Temperature and rainfall conditions during 2008-2009 at Bathinda

Seedless and Perlette while the Selection 7 took maximum days (78) for anthesis. The fruit set was initiated on 74th day and it was completed on 84th day. The varieties Perlette followed by Delight, Beauty Seedless and Ruby Red were earliest to set fruit. Earlier bud burst and sprouting in these varieties might be resulting in earlier fruit set. The varieties Madeliene Anguvine, Banquiabyad, Beauty Seedless and Perlette were among the earlier ripening varieties while the Arka Shyam, Arka Kanchan, Selection 7 and Foster Seedless were among the late varieties. The fruit ripening of all the varieties was initiated on 121 day and was completed 182 days in both the years. This may be due to the reason that the early maturing varieties took lesser number of days from bud burst to fruit set as compared to others varieties resulting in early ripening and vice versa.

Table 1. Days to attain bud burst, sprouting and panicle initiation of grape varieties during 2008 and 2009.

Varieties	Bud Burst		Sprouting		Panicle initiation	
	2008	2009	2008	2009	2008	2009
Cardinal	46	44	48	49	53	54
Angur Early	49	37	51	39	58	42
Banquiabyad	49	43	51	48	57	52
Bharat Early	49	39	51	43	58	49
Madeliene Anguvine	44	32	47	34	50	42
Perlette	38	32	40	34	47	46
Delight	37	33	41	35	48	42
Beauty Seedless	44	32	47	36	50	44
Ruby Red	44	34	47	37	56	42
Black Muscat	49	39	51	41	55	49
Arka Kanchan	49	37	51	39	58	49
Arka Shyam	51	46	57	50	61	54
Selection 7	51	36	56	38	61	49
Lomanto	51	41	51	43	58	49
Foster Seedless	51	36	57	38	58	52
Mean	46.8	37.4	49.7	40.3	55.2	47.7

Table 2. Days to attain anthesis, fruit set and fruit ripening of grape varieties during 2008 and 2009.

Varieties	Anthesis		Fruit set		Fruit ripening	
	2008	2009	2008	2009	2008	2009
Cardinal	73	74	79	78	146	149
Angur Early	78	68	81	81	147	150
Banquiabyad	76	72	79	79	125	127
Bharat Early	76	70	81	80	146	148
Madeliene Anguvine	74	65	77	78	121	121
Perlette	68	70	75	77	132	133
Delight	71	68	74	80	143	143
Beauty Seedless	69	69	76	78	125	129
Ruby Red	69	66	76	78	135	130
Black Muscat	72	70	78	82	149	151
Arka Kanchan	76	71	79	82	149	178
Arka Shyam	75	73	78	84	149	182
Selection 7	80	71	83	82	151	170
Lomanto	78	70	81	82	135	137
Foster Seedless	76	71	80	82	143	175
Mean	74.1	69.9	78.5	80.2	139.7	148.2

Heat unit requirement of grape varieties

All the grape varieties under study consumed varied amount of heat units in both the years to attain different phenological stages (Table 3&4). Most of the grape varieties accumulated less heat units resulting in better yield response and highest heat use efficiencies during first year as compared to second year. Different grape varieties consumed 21.3 - 162.7 and 152.1- 275.2 (°C day) heat units for bud burst and 47.6 - 233.9 and 168.3 - 312.4 (°C day) heat units for sprouting during first and second year, respectively.

Table 3. Heat unit accumulation at bud burst, sprouting, panicle initiation and anthesis of grape cultivars during 2008 and 2009.

Varieties	Bud Burst		Sprouting		Panicle initiation		Anthesis	
	2008	2009	2008	2008	2008	2009	2008	2009
Cardinal	110.2	255.0	129.0	303.4	185.0	351.0	445.8	597.3
Angur Early	139.3	193.8	162.7	208.6	247.2	232.4	501.9	514.6
Banquiabyad	139.3	242.7	162.7	294.4	233.9	330.0	474.9	563.7
Bharat Early	139.3	208.6	162.7	242.7	247.2	303.4	474.9	537.4
Madeliene Anguvine	88.4	152.1	119.5	168.3	150.1	232.4	455.8	487.4
Perlette	28.6	152.1	47.6	168.3	119.5	275.2	379.2	537.4
Delight	21.3	160.2	57.9	176.5	129.0	232.4	423.3	514.6
Beauty Seedless	88.4	152.1	119.5	185.3	150.1	255.0	394.5	525.6
Ruby Red	88.4	168.3	119.5	193.8	219.4	232.4	394.5	497.4
Black Muscat	139.3	208.6	162.7	222.6	206.6	303.4	437.3	537.4
Arka Kanchan	139.3	193.8	162.7	208.6	247.2	303.4	474.9	549.3
Arka Shyam	162.7	275.2	233.9	312.4	284.0	351.0	466.4	580.7
Selection 7	162.7	185.5	219.4	201.6	284.0	303.4	534.2	549.3
Lomanto	162.7	222.6	162.7	242.7	247.2	303.4	501.9	537.4
Foster Seedless	162.7	185.5	233.9	201.6	247.2	330.0	474.9	549.3
Mean	118.2	197.1	150.4	222.1	213.2	289.3	455.6	538.6

Table 4. Heat unit accumulation at fruit set, fruit ripening, fruit yield and HUE of grape cultivars during 2008 and 2009.

Varieties	Fruit set		Fruit ripening		Fruit yield (t/ha)		HUE (kg/acre/°C)	
	2008	2009	2008	2008	2008	2009	2008	2009
Cardinal	517.7	648.0	1858.8	2157.4	36.41	23.32	7.84	4.32
Angur Early	521.2	681.7	1876.1	2178.4	30.14	22.99	6.42	4.23
Banquiabyad	517.7	659.5	1406.5	1646.0	12.10	11.11	3.45	2.70
Bharat Early	521.2	670.0	1858.8	2140.7	7.70	10.12	1.65	1.90
Madeliene Anguvine	486.9	648.0	1333.9	1504.3	24.20	28.93	7.24	7.70
Perlette	466.4	635.6	1548.9	1784.2	29.81	33.33	7.69	7.46
Delight	455.8	670.0	1796.7	2025.3	10.23	8.03	2.28	1.59
Beauty Seedless	474.9	648.0	1406.5	1693.5	31.79	21.78	9.04	5.15
Ruby Red	474.9	648.0	1614.2	1718.8	7.92	4.18	1.95	0.96
Black Muscat	501.9	696.6	1914.9	2199.4	18.59	22.00	3.89	4.00
Arka Kanchan	517.7	696.6	1914.9	2807.2	20.79	18.70	4.34	2.66
Arka Shyam	501.9	731.2	1914.9	2901.4	10.23	16.72	2.13	2.30
Selection 7	584.3	696.6	1949.5	2645.0	13.64	10.23	2.80	1.55
Lomanto	521.2	696.6	1614.2	1884.6	12.87	16.61	3.19	3.53
Foster Seedless	534.2	696.6	1796.7	2746.6	9.90	11.11	2.20	1.62
Mean	506.5	674.9	1720.4	2135.5	18.42	17.28	4.4	3.4
CD at 5%					5.80	5.30		

Similarly, for panicle initiation the different varieties require 119.5 - 284.0 and 232.4 - 351.0 (oC day) heat units during first and second year, respectively. Delight consumed minimum heat units of 129.0 (°C day) for panicle initiation during first season while the maximum heat units of 351.0 °C day were consumed by cultivar Cardinal and Arka Shyam during second season. The heat unit requirement for anthesis of the varieties under study varied from 379.2 - 534.2 and 487.4 - 597.3 (°C day) during first and second year, respectively. The minimum heat units were consumed by the Perlette followed by Ruby Red and Beauty Seedless and the maximum by Cardinal. The heat unit requirement for fruit setting of all the cultivars ranged from 455.8 - 731.2 (°C day) in both the years. The varieties Delight followed by Perlette, Beauty Seedless and Ruby Red consumed minimum heat units for fruit setting while the maximum heat units were consumed by Arka Shyam. Early ripening varieties *i.e.*, Madeliene Anguvine and Banquiabyad consumed lesser heat units of 1419.1 and 1526.3 °C day, respectively whereas the late varieties *i.e.*, Arka Shyam, Arka Kanchan and Lomanto consumed maximum heat units of 2408.2, 2361.1 and 2297.3 °C day, respectively, during both the years. Makhija *et al.* (1984) also reported that the early ripening varieties consumed lesser heat units as compared the late ripening varieties.

Fruit yield (t/ha)

Fruit yield of the varieties under study varied during both the years (Table 4). The fruit yield was recorded significantly higher in Cardinal (36.41 t/ha) which was at par with the fruit yield of Beauty Seedless (31.79t/ha) during the first year. During the second year, significantly higher fruit yield was recorded in Perlette (33.33 t/ha) followed by Madeliene Anguvine (28.93 t/ha). On an average, fruit yield was observed higher during the first year as compared to second year indicating that the weather conditions were more conducive for growth and development of the crop during first year in comparison to second year. In both the years, fruit yield was observed maximum in Perlette followed by Cardinal, while the Ruby Red followed by Bharat Early and Delight were among the lowest fruit yielding varieties. These results are also in conformity with the findings of Thakur *et al.* (2008).

Heat-use efficiency (HUE)

The data presented in Table 4 indicate that the growth rate of Perlette was highest as compared to the others, considering the higher HUE of both years. The heat use efficiency was highest in Beauty Seedless (9.04 kg/°C day) followed by Cardinal (7.84 kg/°C day) and Perlette (7.69 kg/°C day) during the first year. However, during the second year, the highest heat use efficiency of 7.70 kg/°C day was observed in Madeliene Anguvine followed by Perlette (7.46 kg/°C day). The lowest heat use efficiency was observed in Bharat Early (1.65 kg/°C day) followed by Ruby Red (1.95 kg/°C day) during the first year and vice versa during the second year. This may be the reason of the lower fruit yield in Bharat Early and Ruby Red. The value of heat use efficiency was slightly higher during the first year in most of the varieties as compared to second year which indicates that the thermal environment was more favorable in the first year.

Regression models to predict phenology

Simple linear models were developed between the number of days to reach different phenophase and cumulative heat units (Table 5). A significant positive correlation was found between number of days and cumulative heat units in different phenological stages. Higher values of r^2 (0.99) were found for almost each stage, which indicates that these are highly

Table 5. Phenophase prediction model based on cumulative heat units in grapes

Phenophases	No. of days & cumulative heat unit	
	Equation	R^2
Bud burst	Y = 9.44 X – 240.1	0.99
Sprouting	Y = 10.01 X – 264.5	0.99
Panicle initiation	Y = 11.10 X – 319.7	0.99
Anthesis	Y = 12.71 X – 418	0.99
Fruit set	Y = 14.51 X – 558.8	0.96
Fruit ripening	Y = 22.38 X – 1292.3	0.99

correlated with heat units and upto 99 per cent variation is due to weather parameters. Early bud burst in Perlette and Delight resulted in earlier sprouting, panicle initiation, anthesis and fruit set, which ultimately resulted in earlier fruit ripening.

CONCLUSION

Madeliene Anguvine, Banquiabyad, Beauty Seedless and Perlette are the early ripening varieties suitable for cultivation under South-Western region of Punjab, while Arka Shyam and Arka Kanchan are late ripening varieties. Early ripening varieties consumed lesser heat units in comparison to late ripening varieties. Perlette, Cardinal, Beauty Seedless, Angoor Early and Madeliene Anguvine are among the high yielding varieties under study. The growth rate of the variety Perlette, Madeliene Anguvine, Beauty Seedless and Cardinal was highest as compared to the other varieties under study as indicated by the highest heat use efficiency. A significant positive correlation was found between number of days and cumulative heat units.

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Nitrogen management schedule for *Bt* cotton under different planting geometries in semi-arid north-western plains of India

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ABSTRACT

Cotton occupies a predominant position amongst all cash crops in India. However, the full proof agronomic practices are still lacking, particularly for *Bt.* cotton. Therefore, a field experiment was conducted at research farm of ICAR-IARI, New Delhi during kharif seasons of 2013 and 2014 to determine precise nitrogen (N) application rate and planting geometries for *Bt.* Cotton. The treatments consisted of four planting geometries viz., 75 × 60 cm (R), 75 × 45 cm, 60 × 45 cm and 90 × 60 cm and five N-application methods *viz.*, recommended dose of N (RDN), site specific nutrient management using SPAD meter (SPAD index <35), (SSNM), soil test crop response (STCR) approach (140 kg/ha), GreenSeeker (0.67 NDVI) and N-rich strip. The results showed that the highest seed cotton yield (2.13 t/ha) was recorded in N-rich strip where 25 kg N/ha more N was applied as compared to the RDN and this treatment was successively followed by the treatment where N was applied at NDVI 0.67 (2.01 t/ha) and these two treatments were statistically at par with each other. Among different planting geometries studied, the highest seed cotton yield, leaf area, leaf area index, dry matter, number of bolls/plant, number of sympodial branches plant^{-1} were recorded with 75 × 60 cm planting geometry. Thus SPAD meter and GreenSeeker aided site specific N application and planting spacing 75 × 60 cm can be adopted for improving *Bt.* cotton productivity in the north-western plains of India.

Key words: *Bt* Cotton, SPAD meter, Greenseeker, planting geometries

Cotton *(Gossypium hirsutum)* is mainly grown for fiber purpose, however it has many valuable uses as its seed comprises of 30% starch, 25% crude oil and 16.2% protein (Cobley and Steel, 1976). In India cotton is grown over an area of 12.5 mha with total production of 0.34 m cotton bales. *Bt*-cotton accounts for 90% of total cotton area in the country. Nitrogen (N) management in the cotton is one of the most important practices to obtain high-yield and quality fiber. Both deficiency and excess of N adversely affect plant growth and development, retention of bolls, seed cotton yield, lint yield and quality of fiber. An under application of N can cause detrimental losses to yield proportional to the fertilizer shortfall, depletion of the soil N reserve, and depletion of soil fertility (Nichols and Green, 2003). Over-fertilization results in excessive vegetative growth, decreased lint turnout, increased wilt disease incidence, delay in maturity which may results in immature fiber, adversely affecting lint yield and fiber quality (Main *et al.*, 2011; Main *et al.*, 2010). Application of N more than recommended dose not only increases production costs, but also causes severe environmental problems, like groundwater contamination by NO_3- leaching, *etc.* (Zhao *et al.*, 2009; Hunt *et al.*, 1997). The N requirements of cotton plant are not constant throughout the crop growth. At early stage of crop, only a small amount of N is required for vegetative growth, which is generally less than 25% of the total quantity of N required by crop in entire season (Guthrie, 1991).

Sun-Hong Chun *et al.* (2006) from China observed that plant height of *Bt* cotton 'CCR129' was significantly improved with increase in N dose from 0 to 187.5 and to 375 kg/ha. Srinivasan (2006) tested two *Bt*. hybrid under graded levels of fertilizers (80:40:40, 100:50:50 and 120:60:60 kg NPK/ha) observed a significant increase in plant height with increasing levels of fertilizers. Singh (2008) reported that the plant height, leaf area index, dry matter production, crop growth, yield attributing characters and seed cotton yield significantly increased with increase in level of N from 0 to 150 kg/ha. Introduction of *Bt* cotton hybrids, resulted in reduction of insecticide use by at least 50-75% besides ensuring favourable ecological, economical and sociological returns in contrast to the harmful effects of use of insecticides on a large scale (Kranti, 2002). But the full proof agronomic practices are still lacking specially with respect to the N application rate and time and spacing in *Bt*. cotton. Therefore, the present investigation was carried out to determine the effect of precise nitrogen (N) management and planting geometries on growth and productivity of *Bt*. Cotton.

MATERIALS AND METHODS

A 2-year field experiment was conducted at research farm of IARI, New Delhi during kharif seasons of 2013 and 2014. The treatments consisted of four planting geometries, 75 × 60 cm (R), 75 × 45 cm, 60 × 45 cm and 90 × 60 cm and five N-application rates *viz.*, Recommended dose of nitrogen (RDN), site specific nitrogen management (SSNM) using SPAD meter (SPAD index ≤ 35), soil test crop response (STCR) approach (140 kg/ha), Green Seeker (0.67 NDVI) and N-rich strip. The experiment was laid-out in split-plot design replicated three time. The data on various growth and yield parameters were recorded for two years and pooled for analysis of variance. Soil of IARI farm belongs to order Inceptisol, Mahauli series having sandy loam texture in upper 30 cm layer and loam below that. Water table remained below 3.5 m deep from ground surface during crop growth period. A composite representative soil sample was collected from the experimental field prior to experimentation and analyzed for soil physical and chemical properties. Soil of the experimental site was sandy loam, low in organic C (0.41%) and available N (176.7 kg ha^{-1}), medium in phosphorus (11.2 kg ha^{-1}) and potassium (182.5 kg/ha^{-1}), having pH (7.5) and EC (0.33 dS m^{-1}).

Plant height of five randomly selected plants in each plot was measured from the base to the tip of the plant at harvesting during the seasons. Leaf area of five randomly selected plants was measured with the help of leaf area meter (Model LI-3100, USA). Leaf area index (LAI) was computed using the following formula:

$$\text{LAI} = \frac{\text{Total leaf area/plant}}{\text{Ground area covered by the plant}}$$

For determining dry matter accumulation, five randomly selected plants were cut at the ground level at the time of first picking and samples were sun dried for four days. Sun dried samples were transferred into a thermostatic drying oven and were dried at 65°C (36 to 48 hrs) to obtain a constant dry weight. Numbers of sympodial and monopodial branches per plant were counted at the time of harvest of crop based on five tagged plants from sampled row and expressed as per plant basis. Number of bolls/plant was counted from five tagged plants in each plot and was averaged to get the number of bolls $plant^{-1}$. Twenty randomly selected open bolls in each plot were picked, weighed and averaged to get the weight $boll^{-1}$. Seed cotton of five randomly tagged plants used for taking other yield attributes were separated out and weighed and expressed as seed cotton yield per plant. Seed cotton yield from three pickings were weighed separately and were added to get seed cotton yield. After the final picking was over, the aerial part of standing crop was harvested from soil surface.

RESULTS AND DISCUSSION

Growth characteristics

The results of the study showed that the highest leaf area, dry matter and leaf area index were recorded in N-rich strip and this treatment was on par with the treatment where N was applied according to the NDVI values measured using Green Seeker as we have applied about 25

Table 1. Effect of different levels of nitrogen and planting geometry on growth parameters.

Treatments	Plant height (cm)	Leaf area plant^{-1} (cm^2)	Dry matter (g plant^{-1})	LAI
N-application methods				
RDN (150 kg ha^{-1})	135	335	298	4.28
Plant based (SPAD $\leq$ 35)	139	338	306	4.38
STCR (140 Kg ha^{-1})	145	341	305	4.56
Green Seeker (0.67)	145	355	335	4.65
N- rich strip	151	362	341	4.51
LSD (P=0.05)	NS	18	21	0.26
Planting geometry				
60 × 45 cm	125	311	275	3.19
75 × 60 cm	130	330	291	4.26
90 × 60 cm	133	316	279	2.95
LSD (P=0.05)	NS	9	10	0.23

STCR: Soil test crop response; RDN: Recommended dose of nitrogen

kg less N in this treatment compared to RDN and these two treatments were superior to rest of the treatments (Table 1). The lowest plant height, leaf area, dry matter and LAI were obtained with RDN. This shows that there is a scope and need to standardise the optimum amount of N fertilizer for realizing potential yield of *Bt* cotton. Among different planting geometries studied, the highest leaf area, dry matter and LAI were recorded by 75 × 60 cm planting geometry that led to accommodating of 22,222 cotton plants ha^{-1}. In 60 × 45 cm (37,037 plants ha^{-1}) higher density posed competition and in 90 × 60 cm (18,519 plants ha^{-1}) lesser plant density contributed towards lesser leaf area, dry matter and LAI and ultimately reduced the seed cotton yield. These findings are in agreement with the results obtained by Shah *et al.* (2012) who observed a positive effect of increasing levels of N fertilizer from 100-175 kg ha^{-1} on plant height, leaf area index (LAI), dry matter production, crop growth rate (CGR) in *Bt* cotton, although the highest values of these parameters were recorded with application of 175 kg N ha^{-1}.

Plant vigour

There are several spectral indices which are used in agriculture. Spectral vegetation indices are the most important one and they attempt to measure biomass or vegetative vigour. A vegetation index is a dimensionless, radiometric measure that functions as indicator of relative abundance and activity of green vegetation often including LAI, percentage green cover, chlorophyll content, green biomass and absorbed PAR. The normalized difference vegetation index (NDVI) is used to highlight the vegetation component in a soil background and due to normalization also minimizes the effects of illumination and other measurement conditions. This allows a comparison of the same crop across space and over time. The temporal variation of spectral parameters *i.e.* infrared: red reflectance ratio or radiance ratio (RR) and normalized difference vegetation index (NDVI) during the life cycle of crop represent the growth and development of the crop. The plant vigor of cotton is greatly affected by the amount of N-fertilizer applied. Fig. 1 showed that the vigour of plants receiving nitrogen in N-rich strip has an edge throughout the growth period of the crop over rest of the treatments which has been ultimately reflected in highest seed cotton yield of this treatment.

Yield contributing characters and seed cotton yield

The yield contributing characters and seed cotton yield were also significantly influenced by different N treatments. The results of the experiment showed that in general, N-application using SPAD meter (SPAD $\leq$ 35) and Green Seeker

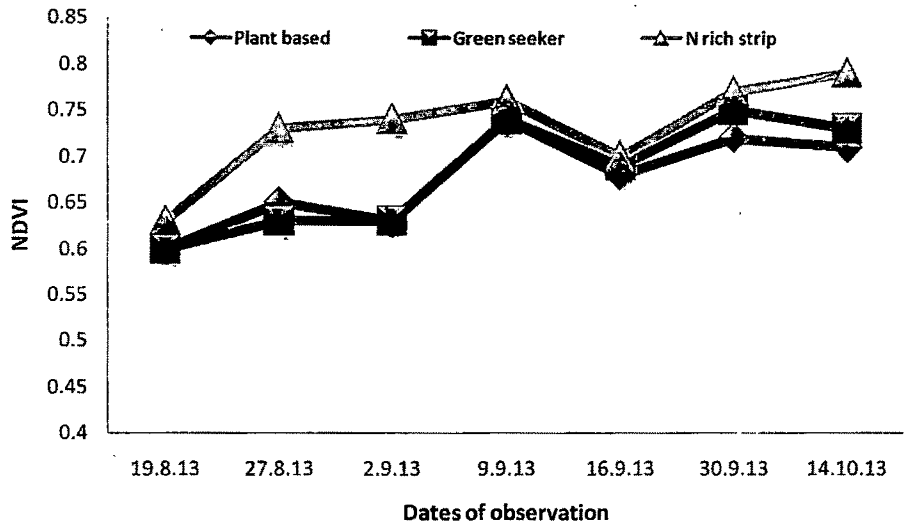

Fig. 1. Cotton vigour as affected by N application

(NDVI 0.67) saved about 20-25 kg N ha^{-1} as compared to recommended nitrogen application in *Bt* cotton. Although, the highest seed cotton yield was obtained in N-rich strip, but the most economical seed cotton yield was recorded where N was applied according to the NDVI values (0.67) coming from Green Seeker. Both these treatments were on par with each other but superior to rest of the treatments. The highest seed cotton yield (2.13 t ha^{-1}) was recorded in N-rich strip and this treatment was on par with the treatment (2.01 t ha^{-1}) where N was applied according to the NDVI values coming from GreenSeeker. Moreover under latter treatment, about 25 kg ha^{-1} less N was applied compared to recommended N schedule. Seed cotton yield resulting from these two treatments were significantly greater than rest of the treatments (Table 2 and Fig. 2). The third best option was soil test crop response where 140 kg N ha^{-1} was applied. This trend was also supported by maximum number of sympodial branches (23.1 plant^{-1}) and number of bolls plant^{-1} (129) and this treatment was successively followed by application of N with Green Seeker. The highest seed cotton yield recorded from N-rich strip was

Table 2. Effect of different levels of nitrogen and planting geometry on yield contributing parameters and seed cotton yield.

Treatments	Yield (kg ha^{-1})	Sympodial branches plant^{-1}	Monopodial branches plant^{-1}	Bolls plant^{-1}
N-application methods				
RDN (150 kg ha^{-1})	1885	19.23	2.5	86
Plant based (SPAD $\leq$ 35)	1897	20.65	2.4	105
STCR (140 kg ha^{-1})	1997	20.45	2.5	116
Green Seeker (0.67)	2014	22.95	2.4	123
N rich strip	2134	23.13	2.6	129
LSD (P=0.05)	136	2.18	0.15	6.1
Planting geometry				
60 × 45 cm	1827	18.12	2.5	69.8
75 × 60 cm	1909	19.10	2.4	86.4
90 × 60 cm	1613	17.96	2.6	91.5
LSD (P=0.05)	85	0.95	0.13	9.8

STCR: Soil test crop response; RDN: Recommended dose of nitrogen

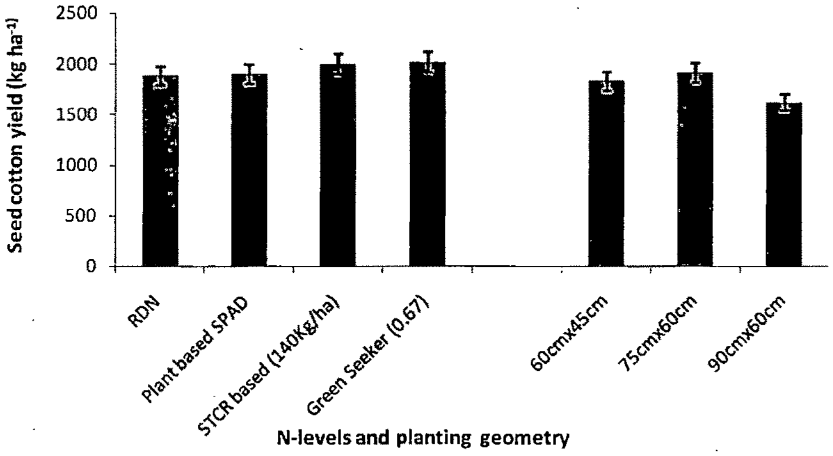

Fig. 2. Seed cotton yield as affected by different N-levels and planting geometry

5.9, 6.9, 12.5 and 13.2 % higher than GreenSeeker, STCR, plant based (SPAD $\leq$ 35) and RDN treatments, respectively. These findings are in agreement with the results obtained by Shah *et al.* (2012) and Nehra (2004). Dass *et al.* (2012) and Dass *et al.* (2014) reported that rainy season maize yield was significantly higher under Chlorpphyll meter (SPAD $\leq$ 37.5) based N application that also saved 30 kg N ha^{-1}.

Among different planting geometries studied, the highest number of sympodial branches (19.1 plant^{-1}) and seed cotton yield (1.91 t ha^{-1}) was recorded by 75 × 60 cm planting geometry consisting of 22,222 plants ha^{-1} followed by 60 × 45 cm (37,037 plants ha^{-1}). However, the highest number of bolls plant^{-1} was recorded with 90 × 60 cm plant spacing. In 60 × 45 cm (37,037 plants ha^{-1}) higher density pose a competition and in 90 × 60 cm (18,519 plants ha^{-1}) lesser plant density contributed towards lesser leaf area, dry matter and LAI and ultimately reduced the seed cotton yield (Table 2). Anand *et al.* (2009) also reported significant effects of planting spacing on growth and yield of Bt. cotton. Their study revealed that seed cotton yield was significantly higher with 75 x 30 cm (2389 kg/ha) spacing, while yield per plant, mean boll weight, number of good opened bolls per plant and total number of bolls opened per plant were significantly higher with 90 × 60 cm spacing. While, Shukla *et al.* (2013) observed the higher growth and yield of cotton hybrids at 60 × 60 cm over wider spacing of 90 × 60 cm planting interval in Vidarbha region of Maharashtra.

CONCLUSION

On the basis of present investigation it can be interpreted that for achieving higher crop yield and optimum utilization of resources nitrogen should be applied according to the crop need assessed by either GreenSeeker or SPAD meter, and crop should be planted at a spacing of 75 × 60 cm.

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Performance of wheat genotypes at different dates of sowing under irrigated conditions

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ABSTRACT

A field experiment was conducted at Nidhauli Kalan, Etah, during the *Rabi* season of 2009-10 to find high yielding genotype of wheat with suitable sowing time. Research indicated that when the sowing was delayed from normal to late (December 12th) and very late (January 2nd), the biological yield was reduced to the tune of 7.0 and 13.2%, respectively. The increase in grain yield with normal sowing was 22.7% and 45.6% when compared with late and very late sowing especialy. Genotype HD-2985 was significantly higher seed yield as compared to all other genotypes. Genotype PBW-343 suspected in higher grain yield by 8.88 and 23.75% over rest of the genotypes. Highest the net return of Rs. 41990.7 ha^{-1} and B:C ratio of 2.0 were obtained with wheat genotype HD 2985 when sown at normal time (18th November).

Key words: Genotypes, wheat, date of sowing.

Wheat *(Triticum aestivum L. and T. durum)* is one of the important food crops of the world and is usually accorded a premier place among cereals because of the vast acreage devoted to its cultivation. Wheat is grown in India over an area of about 28.04 million ha with a production of 78.57 million tonnes. The national productivity is about 28 q ha^{-1}. In India around 80% of the area under wheat is irrigated and about 85% of the total wheat production is contributed by five states (U.P., Punjab, Haryana, M.P. and Rajasthan). Though Uttar Pradesh has the highest total production in India, it lags behind Punjab and Haryana, in terms of yield. Better irrigation facilities in these states are responsible for higher yield. Under irrigated conditions, the first fortnight of November is considered to be the optimum time for sowing the medium-long duration wheat, all over India. For short-duration varieties, the second fortnight of November is the optimum time. In eastern India, the sowing of wheat is often delayed owing to the late harvesting of paddy. The sowings in such cases may go up to even the third week of December. The choice of right genotype of wheat helps to augment crop productivity by about 20-25%. Thus, the value of stable and high yielding genotypes has been universally recognized as an important factor for boosting crop production.

Hence, this experiment was carried out to find out an adaptive and high yielding genotype of wheat and to determine the suitable sowing date under irrigated condition.

MATERIALS AND METHODS

Field experiment was conducted during Rabi season of 2009-10 at Agriculture Research Farm of Shri F.H. (P.G.) College of Science, Agriculture & Forestry, Nidhauli Kalan, Etah, (27°10' N and 78°50' E). The soil of experimental site is sandy loam soil in texture and had 0.50% organic carbon, 181.0, 25.6 and 292.0 kg nutrients ha^{-1} in 0-30 cm soil layer. Initial pH and electrical conductivity (dSm^{-1}) was 7.9 and 1.8, respectively. During the germination and early stages of crop growth, the maximum temperature ranged between 23-26°C, while that of minimum temperature ranged between 6.2 to 16.2°C. During further stages of crop growth (up to February 15), maximum temperature ranged between 15.20 to 26.3°C, while minimum temperature ranged between 4.5° to 10.4°C. This shows that maximum and minimum temperature at growing period of wheat was almost similar to that of normal values.

The treatment comprises of three dates of sowing *viz.* 18th Nov. (Normal) and 12th Dec. (Late) and 2nd Jan. (very late) in main plots and nine genotypes PBW- 610, WH-1061, WH-1062, WH-1063, HD-2985, PBW-373(C), DBW- 16(C), PBW-590 (i) and PBW- 343(TC) in sub-plots. The full dose of phosphorus and potash along with one-third of N were applied as basal and rest 2/3rd N was applied at first node stage.

RESULTS AND DISCUSSION

The plant height was significantly reduced with delay sowing. At harvest, the reduction in plant height with late (December 12th) and very late (January 2nd) sowing was to the tune of 10.1 and 20.9%, respectively over normal date of sowing . At harvest, the reduction in dry matter accumulation was to the tune of 7.0 and 13.2% due to delay (December. 12th) and very delay (January 2nd) of sowing, respectively when compared with normal date of sowing (November 18th). The increase in spike length with normal sowing (D_1) was to the tune of 23.4 and 36.3%, respectively over late (D_2) and very late (D_3) dates of sowing, respectively. The reduction in the number of grains $spike^{-1}$ was to the tune of 20.4 and 27.2% with late (D_2) and very late (D_3), respectively. The maximum weight of grains $spike^{-1}$ was recorded with normal seeding (D_1) treatment and it was found significantly superior over late (D_2) and very late (D_3) treatments. The reduction in 1000 grain weight with late (D_2) and very late (D_3) was to the tune of 4.94 and 11.06%, respectively when compared with normal date of sowing (D_1).

Normal sowing (D_1) resulted in significantly higher grain yield compared to with late (D_2) and very late (D_3) date of sowing, respectively. Late sowing also had appreciably higher grain yield by 10.9% than very late sowing dates of sowing exhibited significant variation in straw yield. The maximum straw yield was recorded with normal

Table 1. Growth and yield attributes of wheat as influenced by date of sowing and genotypes.

Treatments	Plant height (cm)	Dry matter accumulation (g)	Length spike (cm)	Grains $spike^{-1}$	Grains weight $spike^{-1}$ (g)	1000 grain weight (gm\)
Date of sowing						
D_1	115.3	97.4	9.20	45.1	1.94	42.89
D_2	104.8	91.1	7.45	37.4	1.53	40.87
D_3	95.4	86.1	6.75	35.4	1.18	38.62
P=0.05	7.7	4.5	0.65	1.5	0.14	1.30
Genotype						
G_1 - PBW610 (P=0.05)	101.5	88.6	6.60	35.9	1.31	38.16
G_2 - WH 1061 (P=0.05)	101.5	91.4	6.97	36.9	1.41	39.95
G_3 - WH 1062 (P=0.05)	101.5	92.1	7.46	38.1	1.52	41.49
G_4 - WH 1063 (P=0.05)	107.4	93.1	7.78	37.8	1.54	42.15
G_5 - HD 2985 (P=0.05)	111.4	96.5	8.74	43.8	1.73	40.74
G_6 - PBW 373(c) (P=0.05)	103.5	90.1	8.03	39.4	1.57	41.05
G_7 - DBW 16 (c) (P=0.05)	102.7	84.4	8.11	39.7	1.58	41.08
G_8 - PBW 590 (P=0.05)	111.5	91.6	8.10	40.2	1.62	41.72
G_9 - PBW343 (c) (P=0.05)	105.2	95.9	8.41	41.9	1.66	40.77
CD (P=0.05)	6.7	3.4	0.38	0.9	0.08	0.95

Table 2. Yields (t ha^{-1}) and harvest index of wheat as influenced by date of sowing and genotypes.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Date of sowing				
D_1	4.37	6.67	11.04	39.6
D_2	3.56	5.72	9.28	38.4
D_3	3.00	5.06	8.06	37.2
CD (P=0.05)	0.39	0.46	0.58	1.1
Genotype				
G_1 - PBW610 (P=0.05)	3.01	5.02	8.03	37.5
G_2 - WH1061 (P=0.05)	3.03	5.05	8.07	37.5
G_3 - WH 1062 (P=0.05)	3.06	5.26	8.32	36.8
G_4 - WH 1063 (P=0.05)	3.10	5.22	8.32	37.3
G_5 - HD 2985 (P=0.05)	3.88	6.38	10.27	37.8
G_6 - PBW 373(c) (P=0.05)	3.39	5.67	9.25	36.6
G_7 - DBW 16 (c) (P=0.05)	3.41	5.93	9.34	36.5
G_8 - PBW 590 (P=0.05)	3.42	5.76	9.38	36.5
G_9 - PBW343 (c) (P=0.05)	3.73	6.16	9.88	37.7
CD (P=0.05)	0.27	0.35	0.45	0.80

date (D_1) of seeding which was appreciably higher by 16.6 and 31.8% than late (D_2) and very late (D_3) dates of seeding, respectively. The late sowing also resulted in significantly higher straw yield by 13% than very late date of sowing. These results are close conformity with the finding of Kumar and Sharma (2003), Malik *et al.* (2005), Sial *et al.* (2005) and Dhaka *et al.* (2007).

Genotype HD 2985 recorded maximum crop stand at it was higher over WH 1061, WH 1062, WH 1063 and PBW 273 and at par with PBW 610, DBW 16, PBW 590 and PBW 343. The more number of shoots m^{-1} row length with the genotype HD-2985 might be attributed to its better growth under prevailing weather conditions (Table 1). Genotype PBW 590 had appreciably higher shoot height over rest of the genotypes except HD 2985 and WH 1063. At harvest, the increase in dry matter accumulation per plant in genotype HD 2985 and PBW was 3.72 to 14.45% and 4.08 to 13.6%, respectively over rest of the genotypes. Genotypes HD 2985 produced significantly higher number of grains spike^{-1} as compared to all other genotypes except PBW 343. Genotype PBW 343 also had higher number of grains spike^{-1} as compared to rest of the genotypes. Genotype WH 1063 gave significantly higher 1000 grain weight as compared to all other genotypes except WH 1061 and PBW 590.

Genotype HD 2985 has significantly produced higher grain yield as compared to all other genotypes except PBW 343. Genotype PBW 343 also gave in higher grain yield by 8.8 and 23.8% over rest of the genotypes. The differences in grain yield due to genotypes PBW 610, WH 1061, WH 1062 and WH 1064 were not significant among themselves. The dry matter production, grain and straw yields were considerably higher with genotype HD 2985 and it was at par with the PBW 343, but both the genotypes resulted in appreciably higher yield over rest of the genotypes under test.

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Effect of sodic water, biofertilizer and phosphorus on physical properties of soil, yield attributes and yield of mungbean

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ABSTRACT

A pot experiment was conducted to asses the effect of phosphorus management and biofertilizer in mungbean irrigated with sodic water during 2013. Three levels each of sodic water (control, 3.0 and 6.0 mmol/L), biofertilizer (control, PSB and PSB + VAM) and phosphorus (control, 15 and 30 mg/kg of soil), were tested in factorial randomized block design with three replications. The results indicated that application of irrigation water having RSC 1.0 mmol/L, biofertilizer *viz.* PSB + VAM and phosphorus 30 mg/kg of soil recorded the maximum and significantly higher total and available phosphorus, dehydrogenase enzyme activity, alkaline phosphate activity, total and effective nodules, nodule index, number of pods per plant, grain yield, straw yield and biological yield of mungbean over rest of the treatments. A application of irrigation water having RSC 6.0 mmol/L recorded significantly higher pH, EC and ESP as compared to other treatments. However, pH, EC and ESP did not show any significantly difference under different levels of phosphorus and biofertilizers.

Key words: Mungbean, phosphorus, PSB, RSC and yield

The information on the combined effect of phosphate solubilizing bacteria (PSB) and vesicular arbuscular mycorrhiza (VAM) strains and P levels in which conditions is scanty, therefore, the response of mungbean to "phosphorus and biofertilizer irrigated with sodic water was studies. The quality of irrigation water plays a vital role in crop production. Generally, irrigation water from all sources contains dissolved salts in very low concentration. The use of sodic water for irrigation adversely affects the productivity of soil by influencing the availability of nutrients for the plants and various soil properties (Chauhan *et al.* 1988). This problem aggravates when the carbonate and bicarbonate of sodic water occur in association with sodium, creating the problem of residual sodium carbonate (RSC). Mungbean is an important pulse crop but its productivity, particularly in area having sodic irrigation water is quite low because the crop is very sensitive to sodicity. Inoculation of phosphorus solublizing or mobilizing micro-organisms with legume crops through substitute around 20% P requirement P solublization. The rate of P mineralization depends on microbial activity of free phosphates, which is controlled by the solution P concentration. Solublization of inorganic phosphorus in soil is mostly mediated by microbial activity (*Pseudo-monas straita, Bacillus polymixa, Aspergillus awamori*) due to secretion of organic acids and release of CO_2, which prevents fixation of phosphate ion with chelating effect by production of inorganic acids and proton extrusion or ammonium assimilation (Pattanayak *et al.* 2009). In addition to acid production, these P-solublizing micro-organisms produce phosphates enzyme, which causes solublization of native P in soil. Hence, productivity of mungbean can be increased by proper phosphorus nutrition through the introduction of efficient P-solublizers.

Table 1. Composition of irrigation water

RSC mmol/L	EC (dS/m)	SAR	Ionic composition (mmol/L)						
			Na^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
1.0 Base water	1.31	8.2	10.0	1.5	1.5	0.5	3.5	7.5	1.5
3.0	3.27	16.7	26.4	2.5	2.5	1.0	7.0	12.4	12.3
6.0	3.27	16.7	26.4	2.5	2.5	1.0	8.5	11.0	10.7

Response of different crops to P application on sodic soils have been reported by several workers (Tomar *et al.* 1996 and Yadav *et al.* 2009) and it has been suggested that plants grown on saline and sodic soils may have higher P requirements than normal soils because the work against the osmotic force on absorption, translocation and accumulation of inorganic ions may be accomplished at the expense of phosphate energy, phosphorilated intermediates could act as a carrier or trapping agents of anions and cations and inorganic phosphates are components of buffer system of plants (Pattanayak *et al.* 2009).

MATERIALS AND METHODS

A pot experiment was conducted at Agronomy Farm, College of Agriculture, Jobner during 2013 in Randomized complete block design (RCBD) with three replications. The soil was loamy sand in texture, alkaline in reaction (pH 8.10), low in organic carbon (1.85 g/kg), and available nitrogen (128 kg/ha), medium in available phosphorus (20 kg P_2O_5/ha) and potassium (146 kg K_2O/ha) content. Bulk density, particle density, Na, Ca, Mg, CEC, exchangeable Na and ESP (1.50 Mg m^{-3}, 2.60 Mg m^{-3}, 9.60 me/L, 1.2 me/L, 1.2 me/L, 6.8 cmol (P+) kg/soil, 0.65 cmol/kg and 9.55, respectively) of experimental soil. The experiment was consisted of three levels of sodic water (control, 3.0 and 6.0 mmol/L), three levels of biofertilizer (control, PSB and PSB + VAM) and three levels of phosphorus (control, 15 and 30 mg/kg of soil), thereby, making 27 treatment combinations. The different RSC water were prepared artificially by dissolving required amount of $NaHCO_3$, NaCl, Na_2SO_4, $CaCl_2$ and $MgCl_2$ in base water (control). The tap water (base water) was used for first irrigation in all the pots and later on crop was irrigated 6 times with water of varying RSC during experimentation as per treatment. The composition of prepared water is given in Table 1.

Soil was filled in cylindrical ceramic pots (20 cm diameter and 28 cm height). Each pot contained 10 kg of soil. At the time of filling the pots, the broken pieces of stone were placed on the bottom hole to allow free drainage. The mungbean cv. 'RMG-62' was sown on 18th March, 2013 with a seed rate of 18 kg/ha and a row spacing of 45 cm. The crop was harvested on 29th May, 2013. Fully mature and developed pods from randomly selected five plants from each plot were plucked and number of seeds was counted. The average number of pods and seeds per plants was worked out. After threshing and winnowing the weight of seeds for each net plot area was recorded in kg per plot and then converted to kg/ha.

RESULTS AND DISCUSSION

Soil studies

Effect of irrigation water: The results indicated that application of irrigation water with RSC 6.0 mmol/L significantly increased the soil pH, EC and ESP in mungbean as compared to other treatments. Application of RSC water @ 6.0 mmol/L recorded the maximum pH, EC and ESP over other treatments (Table 2). Increase in pH, EC and ESP of the soil due to use of irrigation water with higher RSC for irrigation is attributed to increased sodicity and decreased Ca in irrigation water because of precipitation of Ca and Mg as carbonates provide more opportunity for Na to be adsorbed on the exchange complex (Minhas and Bajwa 2004 and Naga *et al.*, 2013). Application of low RSC irrigation water (1.0 mmol/L) showed significantly higher total phosphorus, available phosphorus, dehydrogenase enzyme activity and alkaline phosphate activity over rest of treatments.

Table 2. Effect of different RSC water, biofertilizer and phosphorus on pH, EC, ESP, total and available phosphorus, dehydrogenase enzyme activity and alkaline phosphatase activity.

Treatments	pH	EC (dS/m)	ESP (%)	Total P (%)	Available P (kg/ha)	Dehydrogenase enzyme activity (p kat/kg soil)	Alkaline phosphatase activity (μ ml PNP produced/g/h)
RSC water (1.0 mmol/L)							
S_0: 1.0	8.00	2.89	17.21	0.032	9.59	6.00	10.22
S_3: 3.0	8.22	2.67	18.83	0.028	9.36	5.81	9.50
S_6: 6.0	8.41	2.45	20.45	0.025	9.03	5.62	8.72
SEm$\pm$	0.03	0.01	0.08	0.001	0.04	0.06	0.04
CD (P=0.05)	0.07	0.03	0.24	0.003	0.12	0.18	0.12
Biofertilizer							
No inoculation	8.23	2.69	18.85	0.024	8.78	5.60	8.44
PSB	8.22	2.67	18.83	0.028	9.36	5.81	9.50
PSB + VAM	8.19	2.65	18.81	0.034	9.90	6.01	10.50
SEm$\pm$	0.03	0.01	0.08	0.001	0.04	0.06	0.04
CD (P=0.05)	NS	NS	NS	0.003	0.12	0.18	0.12
P level (mg P/kg soil)							
P_0 : Control	8.25	2.65	18.99	0.025	8.96	5.60	8.77
P_{15} : 15	8.21	2.67	18.85	0.029	9.37	5.80	9.40
P_{30} : 30	8.17	2.69	18.65	0.031	9.65	6.03	10.27
SEm$\pm$	0.03	0.01	0.08	0.001	0.04	0.06	0.04
CD (P=0.05)	NS	NS	NS	0.003	0.12	0.18	0.12

Divalent cations enhanced P adsorption relative to monovalent cations, hence soil saturated with Na+ retained less amount of P than those saturated with Ca^{2+} ions (Tisdle *et al.*, 1995). Activities of dehydrogenase and alkaline phosphatase as well as microbial biomass build-up were significantly decreased with increasing level of RSC of irrigation water. The results were in close agreement with the findings of Antil *et al.* (2002) and Tripathi *et al.* (2006).

Effect of biofertilizer : The seed inoculation with biofertilizer significantly influnced the total phosphorus, available phosphorus, dehydrogenase enzyme activity and alkaline phosphate activity in mungbean. The seed inoculation with PSB + VAM significantly increased total phosphorus, available phosphorus, dehydrogenase enzyme activity and alkaline phosphate activity over rest of treatments (Table 2). Kumar, 1998 has also reported that seed inoculation with PSB significantly increased the total and available P in soil after harvest and helped in releasing native P as well as in protecting fixation of added phosphorus. The phosphatase activity in soil at harvest of mungbean over no inoculation of biofertilizer significantly enhanced the alkaline. Increased microbial and root activity in the rhizosphere generally accounts for higher activity including phoshpatase as reported by Singh *et al.* (2012) and Nath *et al.*, (2012).

Effect of phosphorus : The application of phosphorus @ 30 kg/ha significantly increased total phosphorus, available phosphorus, dehydrogenase and alkaline phosphate activity over rest of treatments (Table 2). Maximum soil microbial biomass, total and available phosphorus in soil was recorded under treatment receiving dual inoculation of PSB+VAM and minimum in soil under no inoculation. The application of PSB + VAM significantly enhanced the alkaline phosphatase activity in soil at harvest of mungbean over no inoculation of biofertilizer. Increased microbial and root activity in the rhizosphere generally accounts for higher activity including phoshpatase (Singh *et al.*, 2012 and

Nath *et al.*, 2012). However, pH, EC and ESP did not show significantl differences under different levels of phosphorus.

Yield attributes and yield

Effect of irrigation water : The results indicated that application of irrigation water with RSC 1.0 mmol/L showed significantly higher total and effective, nodule index, number of pods per plant, grain, straw and biological yield in mungbean as compared to other treatments (Table 3). This may be explained on the basis that increasing level of RSC water increased the ESP and pH of soil resulting into decreased availability of P, K, Ca and Mg but increased the uptake of Na which is toxic element. The higher amount of Na might have adversely affected the physiological, metabolic and enzymatic activities and utilization of photosynthates in plant. There are several evidences that cationic (Ca, Mg, Na and K) imbalance could lead to disturbances in photosynthesis and activity of stroma enzymes. The inability of the crop to grow under high RSC water was due to the toxicity of Na itself and Ca and between Na and K frequently becomes as limiting factor for plant growth (Dwivedi and Burrows, 1979). Restricted supply of Ca was reciprocated by a high Na content and was shown to affect the growth of the roots and shoots. Such a reduction in growth under Ca deficiency caused by Na accumulation was attributed to K leakage (Ben-Hauyyim *et al.*, 1987).

Effect of biofertilizer : The seed inoculation of biofertilizer significantly influenced nodulation, yield attributes and yield of mungbean. The seed inoculation with PSB + VAM significantly increased total and effective, nodule index, number of pods per plant, grain yield, straw yield and biological yield as compare to other treatments (Table 3). Seed inoculation with PSB significantly increased the total and available P in soil after harvest of the crop. The significantly enhanced the alkaline phosphatase activity in soil at harvest of mungbean over no inoculation of biofertilizer. Increased microbial and root activity in the rhizosphere generally account for higher activity including phoshpatase Singh *et al.* (2012) and Nath *et al.*, (2012). However, pH, EC and ESP remained materially unchanged under different treatments of biofertilizer. Increase in grain and straw yield due to inoculation of PSB + VAM

Table 3. Effect of different RSC water, biofertilizer and phosphorus on yield attributes and yield of mungbean.

Treatments	Total nodules	Effective nodules	Nodule index	Number of pods/plant	Grain yield (g/pot)	Straw yield (g/pot)	Biological yield (g/pot)
RSC water							
S_0: 1.0	25.00	20.70	2.58	7.69	4.45	6.20	10.65
S_3: 3.0	20.10	16.00	2.49	5.59	3.71	5.70	9.41
S_6: 6.0	15.00	12.50	2.43	4.45	3.06	5.08	8.14
SEm±	0.12	0.09	0.01	0.09	0.05	0.06	0.09
CD (P=0.05)	0.34	0.26	0.02	0.25	0.13	0.18	0.25
Biofertilizer							
No inoculation	15.10	12.50	2.30	4.62	3.07	5.06	8.13
PSB	20.10	16.00	2.49	5.59	3.71	5.70	9.41
PSB + VAM	24.00	19.20	2.70	7.20	4.45	6.21	10.66
SEm±	0.12	0.09	0.01	0.09	0.05	0.06	0.09
CD (P=0.05)	0.34	0.26	0.02	0.25	0.13	0.18	0.25
P level (mg P/kg soil)							
P_0 : Control	15.00	13.60	2.37	4.21	3.05	5.06	8.11
P_{15} : 15	20.10	15.00	2.49	6.40	3.71	5.72	9.43
P_{30} : 30	25.00	20.60	2.64	7.12	4.46	6.20	10.66
SEm±	0.12	0.09	0.01	0.09	0.05	0.06	0.09
CD (P=0.05)	0.34	0.26	0.02	0.25	0.13	0.18	0.25

might be attributed to its phosphate solubilizing effect. PSB solubilize insoluble fixed P in soil by production of organic acids in solubilizing minerals and phosphorylated minerals is attributed to the lowering of pH which helps in release of phosphorus from the stable complexes with cations such as Ca^{2+}, Mg^{2+}. Such reaction also prevent the fixation of phosphate ions. Organic acids solubilize more P than inorganic acids at same pH due to the chelating effect of former (Somani, 2002). Production of CO_2 by soil microorganisms and plant roots leads to formation of carbonic acid which also encourages solubilization of insoluble P. The solubilization of insoluble phosphatase without production of acid may be due to release of protons accompanying respiration or ammonium assimilation and insoluble phosphate, thus directly solubilized at the microbial cell surface (Somani, 2002).

Effect of phosphorus : The application of phosphorus @ 30 kg/ha significantly increased total and effective nodules, nodule index, number of pods per plant, grain, straw and biological yield over rest of treatments (Table 3). Phosphorus has been recognized as an essential constituent of all living organisms and play an important role in the conservation and transfer of energy in the metabolic reaction of living cell including biological energy transformation. It is the main constituent of co-enzymes, ATP and ADP which act as "energy currency" within plants. Thus phosphorus influences photosynthesis, biosynthesis of proteins and phospholipids, nuclic acid synthesis membrane transport and cytoplasmic streaming. The results obtained in this investigation were in close conformity with those of Tiwari and Kumar (2009) and Akbari *et al.* (2010).

CONCLUSION

On the basis of one year field experimentation, it seems quite logical to conclude that grain and straw yield increased with increase in level of phosphorus and seed inoculation with PSB and VAM. However, higher RSC of irrigation water adversely affect the nodulation and yield of mungbean.

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Growth and yield of cowpea as influenced by nitrogen and phosphorus levels on medium black soils of Gujarat

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ABSTRACT

A field experiment was conducted during *kharif* 2012 on medium black soils of Gujarat to the study the effect of nitrogen and phosphorus levels on growth and yield of cowpea. The experiment consisted of four nitrogen (N) levels (control, 20, 30 and 40 kg N/ha) and four phosphorus (P_2O_5) levels (control, 40, 60 and 80 kg P_2O_5/ha) thereby making sixteen treatment combinations tested in factorial randomized block design with three replications. Application of nitrogen and phosphorus @ 40 and 80 kg/ha resulted in maximum and significantly higher plant height, dry matter accumulation, number of branches per plant, chlorophyll content, total & effective and fresh & dry weight of nodules per plant, seed and stover yield and remained at par with 20 & 30 kg N/ha and 40 & 60 kg P_2O_5/ha over control. The combined application of nitrogen and phosphorus @ 20 kg and 40 kg P_2O_5/ha was found significantly better in terms of seed and stover yield over rest of the treatments.

Key words: Cowpea, growth, nitrogen, nodules, phosphorus and yield

Pulses are the important sources of proteins, vitamins and minerals for the predominantly vegetarian population and are popularly known as "Poor man's meat" and "rich man's vegetable" (Singh and Singh, 1992). Pulses contain two to three times more protein than cereals ranging approximately between 20 to 40 per cent (Arora, 1989). Besides this, pulses have a unique property of maintaining and restoring soil fertility through biological nitrogen fixation as well as addition of ample amount of plant residues to the soil. Pulse crops leave behind reasonable quantity of nitrogen in soil to the extent of 30 kg/ha. Cowpea [*Vigna unguiculata* (L.) Walp] commonly known as *lobia* is one of the important pulse crop grown for grain, forage and green manuring include production and productivity of cowpea. The crop gives such a heavy vegetative growth and covers the ground so well that it checks the soil erosion in problem areas and can later be ploughed down for green manure. On dry weight basis, cowpea grain contains 23.4 per cent protein, 1.8 per cent fat and 60.3 per cent carbohydrates. It is also rich source of calcium and iron. Among the various constraints to low productivity of cowpea, inadequate use of fertilizers and lack of improved package of practices are important. Nitrogen plays an important role in various metabolic process of plant. Nitrogen is an essential constituent of protein, chlorophyll and is present in many other compounds helps in plant metabolism, such as nucleotides, phosphatides, alkaloids, enzymes, hormones, vitamins, *etc.* It imparts dark-green colour of plants, produces rapid early growth, improves capacity to fix atmospheric nitrogen symbiotically and it responds to small quantity of nitrogenous fertilizers applied as starter dose. Application of 15 - 20 kg N/ha has been found optimum to get better production response in cowpea. Phosphorus is an essential constituent of nucleic acids and stimulates root growth as well as increase nodule activity in plant. Phosphorus is also an essential primary nutrient and is constituent of nucleic acids such as ribonucleic acid (RNA) and deoxyribonucleic acid (DNA), adenosine diphosphate (ADP) and adenosine triphosphate (ATP), nucleoproteins, amino acids, proteins, phosphotides, phytin and several co-enzymes *viz.*, thiamine, pyrophosphate and pyrodoxyl phosphite. Application of balanced fertilizers up to 25 kg N and 50 kg P_2O_5/ha recorded higher seed and straw yield of cowpea over no fertilization (Patel *et al.*, 2003). Similar response with application of 20 kg N and 60 kg P_2O_5/ha was observed by Vikrant *et al.* (2005). Therefore, the present study, interaction effect of nitrogen and phosphorus level on yield of cowpea was conducted on medium black soil of Gujarat.

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MATERIALS AND METHODS

A field experiment was conducted during 2012 at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh in a factorial randomized block design with three replications. The soil was medium black in texture, alkaline in reaction (pH 7.8), medium in organic carbon (0.57 %), low in available nitrogen (237.0 kg/ha), medium in available phosphorus (32.5 kg P_2O_5/ha) and medium in potassium (269.0 kg K_2O/ha) content. The experiment consisted four levels of nitrogen (control, 20, 30 and 40 kg/ha) and four levels of phosphorus (control, 40, 60 and 80 kg P_2O_5/ha), thereby, making sixteen treatment combinations. Fertilizers were applied as per treatment through single super phosphate (SSP) and urea at the time of sowing as basal dose. The cowpea cv. 'GC-5' was sown on 27 February, 2012 using seed rate of 25 kg/ha with a row spacing of 45 cm. The crop was harvested on 9 May, 2012. Five irrigations were applied during growing season. Intercultural operations *viz.*, thinning, hoeing and weeding were followed after 20 days of sowing to maintain recommended spacing and weed control. For weed management pendimethalin 1.0 kg/ha *a.i.* was applied as pre-emergence to control the weeds in early stages of the crop. Fully mature and developed pods from randomly selected five plants from each plot were plucked and numbers of seeds were counted. The average number of pods and seeds per plants were worked out. After threshing and winnowing the weight of seeds for each net plot area was recorded in kg per plot and then converted to kg/ha.

RESULTS AND DISCUSSION

Growth parameters

Effect of nitrogen levels: Application of nitrogen @ 40 kg/ha recorded significantly higher plant height, dry matter accumulation at 40 DAS and at harvest, number of branches per plant and chlorophyll content and remained at par with 20 and 30 kg N/ha (Table 1). The increase in these components seems to have been brought about by increase in amount of growth substances and naturally occurring phytohormones with increased nitrogen supply. Probably the increase in auxin supply with higher levels of nitrogen brought about increase in the dry matter and branches per plant (Sharma and Dayal, 2005). The increased availability of nitrogen might have increased cell number and cell size leading to better growth in terms of height, number of branches per plant and nodule growth (Keshwa *et al.*, 2009 and Tiwari and Kumar, 2009).

Effect of phosphorus levels: The application of phosphorus levels upto 80 kg/ha resulted in significantly higher plant height, dry matter accumulation at 40 DAS and at harvest, number of branches per plant and chlorophyll content in cowpea as compared to other treatments and remained at par with 40 and 60 kg P_2O_5/ha over control (Table 1). The increased supply of available phosphorus has long been considered as an essential constituent of all living organisms and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformations (Chattopadhyay and Dutta, 2003). The energy obtained from photosynthesis and metabolism of carbohydrates is stored in storage compounds (ATP and ADP) for subsequent use in growth which in turn resulted in vigorous growth of plants.

Yield attributes and yield

Effect of nitrogen levels: The application of nitrogen @ 40 kg/ha recorded significantly increased total & effective weight and fresh & dry weight of nodules per plant, seed, stover and biological yields and remained at par with 20 and 30 kg N/ha (Table 2). The increase in seed and stover yields might be due to better nutritional

Table 1. Effect of nitrogen and phosphorus levels on plant height, dry matter, number of branches per plant and chlorophyll content

Treatments	Plant height (cm)		Dry matter/metre row length (g)		Number of branches/ plant	Chlorophyl content (mg/g)
	40 DAS	Harvest	40 DAS	Harvest		
Nitrogen levels (Kg/ha)						
N_0: Control	43.9	57.8	46.3	76.3	4.27	1.94
N_1: 20	48.6	63.4	56.4	86.7	6.32	2.46
N_2: 30	50.1	64.1	57.9	89.6	6.45	2.50
N_3: 40	52.3	65.5	60.0	91.2	6.62	2.55
S.Em.±	1.33	1.53	1.29	1.76	0.20	0.04
C.D. (P=0.05)	3.84	4.43	3.73	5.08	0.57	0.12
Phosphorus levels (kg/ha)						
P_0: Control	45.0	58.2	45.4	76.7	4.33	2.07
P_1: 40	48.7	62.6	57.0	87.1	6.37	2.40
P_2: 60	50.2	63.7	58.4	89.5	6.30	2.47
P_3: 80	52.6	66.3	60.0	90.6	6.65	2.50
S.Em.±	1.33	1.53	1.29	1.76	0.20	0.04
C.D. (P=0.05)	3.84	4.43	3.73	5.08	0.57	0.12

Table 2. Effect of nitrogen and phosphorus levels on number of nodules per plant and yield of cowpea

Treatments	Number of nodules/plant				Yield (kg/ha)		
	Total nodules	Effective nodules	Fresh weight (g)	Dry weight (g)	Seed	Stover	Biological
Nitrogen levels (Kg/ha)							
N_0: Control	20.5	12.0	333	64.1	769	1915	2684
N_1: 20	25.1	15.6	363	67.7	1013	2125	3138
N_2: 30	25.8	15.8	369	70.9	1018	2133	3151
N_3: 40	26.8	16.9	378	74.7	1022	2141	3163
S.Em.±	0.64	0.47	8.09	2.45	26	47	63
C.D. (P=0.05)	1.86	1.36	23.35	7.06	74	135	182
Phosphorus levels (kg/ha)							
P_0: Control	20.4	12.0	341	62.0	725	1834	2559
P_1: 40	24.9	15.5	359	68.8	1049	2128	3177
P_2: 60	25.5	15.9	369	72.2	1061	2143	3204
P_3: 80	26.7	16.9	374	74.3	1070	2150	3220
S.Em.±	0.64	0.47	8.09	2.45	26	47	63
C.D. (P=0.05)	1.86	1.36	23.35	7.06	74	135	182

status of the crop in the soil (Ilavarasi *et al.*, 2007). The increased supply of nitrogen and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters and resulted in increased seed and stover yields. These results are in close conformity with the findings of Patel *et al.* (2003) and Singh *et al.* (2007).

Effect of phosphorus levels: The increasing levels of phosphorus up 80 kg/ha significantly higher total & effective weight and fresh & dry weight of nodules per plant, seed, stover and biological yields in cowpea as compared to other treatments and remained at par with 40 and 60 kg P_2O_5/ha over control (Table 2). The phosphorus plays an important role in nitrogen-fixation in legumes, where it acts as a source of energy. It plays a pivotal role in early formation of roots, their proliferation, increased microbial activity in nodules and symbiotic biological N-fixation process (Vikrant *et al.*, 2005). This also led to efficient and greater partitioning of metabolites and adequate translocation of photosynthates and nutrients to develop reproductive structures (Tisdale *et al.*, 1995).

Interaction effect of nitrogen and phosphorus levels on seed and stover yield: The combined application of nitrogen and phosphorus @ 20 and 40 significantly increases in term of seed and stover yields and its remained at par with application $N_{20}P_{60}$, $N_{20}P_{80}$, $N_{30}P_{40}$, $N_{30}P_{60}$, $N_{30}P_{80}$, $N_{40}P_{40}$, $N_{40}P_{60}$ and $N_{40}P_{80}$ over rest of treatments (Table 3 and 4). Nitrogen availability is depending more or less on phosphorus. Phosphorus enhances the symbiotic nitrogen (N) fixation process in legume crops and ultimately improved the uptake of nutrients our results are in conformity with those reported by Navale *et al.* (2000) and Badran (2003).

CONCLUSION

On the basis of one year field experimentation, it seems quite logical to conclude that for higher growth parameter, seed and stover yield of cowpea, combined application of nitrogen and phosphorus @ 20 and 40 kg/ha dose can be sufficient on medium black soil of Gujarat.

Table 3. Interaction effect of nitrogen and phosphorus on seed yield (kg/ha) of cowpea

Levels of nitrogen (kg/ha)	Levels of phosphorus (kg/ha)			
	0	40	60	80
0	640	838	941	971
20	804	1121	1061	1024
30	912	1106	1047	1004
40	898	991	1032	1057
S. Em±		51		
C.D. (P=0.05)		148		

Table 4. Interaction effect of nitrogen and phosphorus on stover yield (kg/ha) of cowpea

Levels of nitrogen (kg/ha)	Levels of phosphorus (kg/ha)			
	0	40	60	80
0	1767	1883	1993	2057
20	1803	2328	2217	2070
30	1800	2283	2267	2183
40	1967	2057	2097	2319
S. Em±		94		
C.D. (P=0.05)		271		

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Integrated weed management in raya (*Brassica juncea* L.)

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ABSTRACT

A field experiment was conducted during *rabi* 2010-11 at Department of Agronomy, PAU, Ludhiana to evaluate the bioefficacy of UPH 1110, clodinafop, isoproturon and trifluralin in raya (*Brassica juncea* L.). The experiment comprising ten treatments replicated thrice was laid out in randomized complete block design. The results revealed that the herbicide treatments *viz.* Trifluralin 1l/ha fb one hand weeding at 50 days after sowing, clodinafop 0.40 kg/ha and isoproturon1.0 kg/ha were significantly superior to unweeded control in terms of weed dry matter, yield contributing characters and seed yield. Application of different doses (0.75, 1.0, 1.25 1.50 and 2.50 kg/ha) of UPH 1110 proved very effective in controlling all the weeds as no weed dry matter was recorded however, it was found phytotoxic to the crop as the seed yield was reduced significantly. Therefore, the use of herbicide UPH 1110 was not found safer for weed control in raya.

Key words: Clodinofop isoproturon, phytotoxicity, raya, trifluralin, UPH 1110, WCE.

Weeds are often the principal biotic constraint to crop production as they pose serious threat to crops due to competition for nutrients, moisture, light and space which may go up to 62% (Cudney *et al.*, 2001). This brings about severe interference with normal crop growth. Of the total annual loss of agricultural produce from various pests in India, infestation of weeds, insects, diseases and other pests caused 37, 29, 33 and 12% yield losses, respectively (Yaduraju, 2006). Yield losses due to crop weed competition in rapeseed and mustard have been estimated to the tune of 10-58% (Banga and Yadav, 2001) or even beyond 70% depending upon type, intensity and duration of competition (Chopra and Saini, 2007). Weeds pose competition particularly during initial crop growth stages and later on become a limiting factor to its productivity therefore, control of weeds in the early stage of growth is of high importance. Weed control through hand weeding in this crop is not always feasible due to higher cost involved and it is also difficult affair because of non-availability of labourers as the operation coincides with sowing of most of the other *rabi* crops. In spite of recoding the highest weed control efficiency and providing higher sugar cane yield, hand weeding could not found economical because of higher expenditure incurred on engaging labourers (Kumar *et al.* 2014).

Indian mustard (*Brassica juncea* L.) is an important *rabi* oilseed crop. In Punjab, rape seed and mustard were grown on 29 thousand hectares with a production of 37 thousand tonnes during 2011-12 (Anonymus, 2013-14). Only few herbicides are available for weed management in *Brassica* species however, their unwise usage may cause crop injury and yield losses. Moreover, herbicidal use might disturb ecological balance and create environmental issues as ground water pollution and soil microbial activities. The most common herbicides recommended in Indian mustard in Punjab are isoproturon (pre-emergence) and trifluralin (pre-plant). However, chemical weed control using post-emergence herbicide is of great necessity of the farmers especially where pre-emergence/pre-plant application of herbicide could not be made. Further, under situations when weeds are not taken care completely by pre-emergence application of herbicides, hand weeding and post-emergence herbicides may have an added advantage for timely control of weeds to reduce the yield losses. Therefore, integration of chemical means of weed control using effective herbicides alongwith manual weeding proved to be more suitable and economically viable. Considering these facts, it is difficult to rely solely on a particular weed control method, however integrated weed management, involving two or more techniques with a major component on cultural and physical practices, should be the way to effectively reduce weed burden with minimal risk to the environment. So an experiment was conducted keeping in mind integrated weed management alongwith new herbicide and other recommended herbicides with hand weeding for suitable weed control measure in Indian mustard.

MATERIALS AND METHODS

The experiment was conducted to evaluate the bioefficacy of different herbicides in raya at Experimental Farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* 2010-11. Ten treatments involving different herbicides and doses, including hand weeding and unweeded control were tested in Randomized Block Design with three replication. The soil of the experimental site was sandy loam. The seedbed was prepared by one ploughing with disc harrow followed by three ploughings with cultivator and each ploughing was followed by planking. The crop was sown in the third week of November, 2010 with variety RLM 619 by using recommended seed rate of 3.75 kg/ha. The nutrient doses of 50 kg N, 30 kg P_2O_5 and 15 kg K_2O/ha through urea, single superphosphate and muriate of potash were applied at the time of sowing. Second split of 50 kg N/ha was applied after first irrigation. The herbicide treatments were UPH 1110 at 0.75, 1.0, 1.25, 1.5 and 2.5 kg/ha (post emergence), clodinafop 0.40 kg/ha (post emergence), isoproturon 1.0 kg/ha (pre-emergence), trifluralin 1.0 l/ha (pre plant incorporation) *fb* hand weeding (50 DAS), two hand weedings (25 and 50 DAS) and unweeded control. The herbicides were applied as per treatments with knap sack sprayer fitted with flat fan nozzle. The data on weed count and dry matter accumulation were recorded from two spots randomly selected from each plot using 50 × 50 cm quadrat at 70 days after sowing (DAS). The crop was harvested in the third week of April, 2011 when it turned yellowish brown and thrashed on complete drying in the field.

RESULTS AND DISCUSSION

Effect on weeds

The experimental field was predominantly infested with *Phalaris minor, Anagallis arvensis, Lepidium sativa, Medicago denticulata, Melilotus sp, Chenopodium album, Rumex dentatus etc.* Different weed control treatments significantly influenced weed population and weed dry weight. Post-emergence application of UPH 1110 at 0.75, 1.00, 1.25, 1.50 and 2.50 kg/ha resulted in significant reduction in population of broad leaf as well as grass weeds as compared to unweeded control and other treatments. Though the new herbicide, UPH 1110 found very effective in controlling all type of weed flora but at the same time the herbicide showed a severe phytotoxicity on the crop as reflected through the seed yield (Table 2). Further, the impact of phytotoxicity increased consistently with the increase in doses and caused more than 50% seed yield reduction with the application of UPH 1110 @ 2.50 kg/ha (730 kg) as compared to two hand weeding (180 kg). Application of UPH 1110 irrespective of different doses showed 100% weed control efficiency. Application of trifluralin 1.0 l/ha *fb* HW at 50 DAS also reduced the weed population significantly when compared with control treatment without showing any phytotoxicity to the crop. Similarly, it was found superior to clodinafop and isoproturon in reducing the infestation of grass weeds and weed dry weight. However, Application of trifluralin was not as effective as two hand weedings in terms of weed dry weight as indicated by comparatively lower WCE of 85.8%. The lesser efficiency of trifluralin in reducing weed dry weight might be due to its

Table 1. Effect of different weed control treatments on weed density and dry matter.

Treatments	Dose (kg/ha)	Grass weeds (No./m²)	Broad leaf weeds (No./m²)	Dry weight (kg/ha)	WCE (%)
Trifluralin *fb* HW	1.00	1.1 (0.9)	7.4 (56)	4.3 (7.8)	85.8
UPH 1110	0.75	1.0 (0)	1.0 (0)	1.0 (0.0)	100
UPH 1110	1.00	1.0 (0)	1.0 (0)	1.0 (0.0)	100
UPH 1110	1.25	1.0 (0)	1.0 (0)	1.0 (0.0)	100
UPH 1110	1.50	1.0 (0)	1.0 (0)	1.0 (0.0)	100
UPH 1110	2.50	1.0 (0)	1.0 (0)	1.0 (0.0)	100
Clodinafop	0.40	3.9 (15)	9.8 (107)	57.6 (3478)	36.5
Isoproturon	1.00	2.7 (7)	5.1 (37)	550.2 (2516)	54.0
Two hand weedings	-	1.0 (0)	1.0 (0.)	1.0 (0.0)	100
Control	-	4.4 (19)	13.6 (192)	73.9 (5476)	-
SEm±	-	0.3	1.2	2.1	-
CD (P=0.05)	-	0.9	3.9	6.4	-

* Figures in parenthesis are means of original values. Data is subjected to square root transformation

comparatively poor control on broadleaf weeds. Trifluralin recorded significantly less dry weight of weeds than clodinafop but at par with isoproturon. Application of clodinafop and isoproturon with a WCE of 36.5 and 54% respectively, also recorded significantly less weed dry weight as compared to unweeded control. Significantly higher weed dry matter was recorded in unweeded control as compared to other herbicide treatments due to higher weed population (Table 1).

Effect on crop

Different herbicide treatments showed significant differences on the growth and yield attributing characters like plant height, number of branches and siliquae/plant. All the doses of UPH 1110 herbicide showed higher toxicity on raya crop which was reflected through retarded plant height, lesser number of branches/plant and siliquae/plant resulting in significant reduction in yield and even less than that obtained under unweeded control. Application of different herbicides (except UPH) showed non significant differences in terms of plant height when compared with hand weeding and in unweeded control plots. However, significant reduction in height was recorded in UPH 1110 treatments. Isoproturon at 1.0 and trifluralin 1.0 l/ha *fb* hand weeding resulted in significant increase in plant height as compared to all UPH 1110 doses except lower dose of UPH 1110 at 0.75 kg/ha which was found statistically at par with isoproturon due to effective control of weed flora in these treatments. Application of UPH herbicide irrespective of different doses showed higher toxicity on raya crop due to which significantly lower plant height was observed in these treatments (Table 2).

The maximum number of siliquae per plant was recorded in treatment UPH 1110 at 0.75 kg/ha application which was significantly higher than all other doses of UPH 1110 and at par with trifluralin at 1.0 l/ha, clodinafop at 0.40 kg/ha and two hand weedings due to effective control of weeds and favourable growth of the crop in these treatments. Number of siliquae per plant decreased with the increase in dose of UPH 1110 as this herbicide was highly toxic to the crop. Significantly less number of siliquae per plant was recorded in unweeded control as compared to herbicide treatments due to more weed count and weed dry matter in this plot. The yield contributing characters were at par in trifluralin fb hand weeding, clodinafop and isoproturon treatments (Table 2).

The maximum seed yield was observed in trifluralin at 1.0 l/ha integrated with one hand weeding and at par with two hand weeding treatments which was statistically at par with isoproturon at 1.0 kg/ha and clodinafop at

Table 2. Effect of different weed control treatments on growth and seed yield of raya.

Treatments	Dose (kg/ha)	Plant height (cm)	Branches/ plant	Siliquae/ plant	Seed yield (kg/ha)
Trifluralin fb HW	1.00	198.1	8.6	320.8	1810
UPH 1110	0.75	190.1	7.1	341.6	1420
UPH 1110	1.00	183.9	6.9	292.6	1270
UPH 1110	1.25	174.7	6.1	281.1	950
UPH 1110	1.50	177.6	6.7	278.1	880
UPH 1110	2.50	172.3	5.6	272.5	730
Clodinafop	0.40	188.9	8.3	315.0	1480
Isoproturon	1.00	201.9	8.6	319.2	1730
Two hand weedings	-	197.3	8.9	319.7	1800
Control	-	199.0	7.9	213.9	1380
SEm±		4.4	0.1	4.2	90
CD (P=0.05)	-	14.1	0.4	40.2	300

0.40 kg/ha. These results confirm the findings of Yadav *et al.* (1999). All the doses of UPH 1110 recorded significantly lower seed yield as compared to recommended herbicide treatments due to toxic effect of this herbicide on crop. There was increase in seed yield by 31.2, 7.2, 25.4 and 30.4 in case of trifluralin fb hand weeding, clodinafop, isoproturon and hand weeding treatments as compared to unweeded control. There was negative yield in case of UPH 1110 as compared to unweeded control in this crop. Dinesh *et al.* (2000) also reported that pre-plant application of trifluralin 1.0 kg/ha followed by hand weeding as one of the best treatment in suppressing the intensity of weeds and consequently offset the yield losses caused by weeds. Prusty *et al.* (1996) have reported the phytotoxic effects of isoproturon towards rapeseed mustard when applied as post-emergence. Pre-emergence application of isoproturon was not toxic but gave poor control of weeds.

The maximum seed yield was observed in two hand weedings treatment which was statistically at par with isoproturon at 1.0 kg/ha and trifluralin at 1.0 l/ha. The superiority of the two hand-weedings (25 and 50 days after sowing) may be attributed to better weed control and better aeration to the crop. Similar results were also reported by Yadav *et al.* (1999). The maximum yield-attributing traits were recorded in weed-free and two hand-weedings (25 and 50 days after sowing) whereas the lowest in the weedy check (control) by Chauhan *et al.* (2005) also. In wheat-raya system, use of isoproturon gave higher yields of wheat but lower yield of raya when compared with the pre-emergence application of fluchloralin and pendimethalin. Weed control in terms of population and dry weight of weeds due to post-emergence application of isoproturon was significantly more than fluchloralin (Panwar *et al.* 1987). So it is concluded that application of UPH 1110 at all the above tested doses was not found safe on raya. Its use should be avoided to avoid any major crop loss. However, post emergence application of isoproturon 1.00 kg/ha or pre plant trifluralin1.0 l/ha *fb* one hand weeding at 50 DAS were found as promising herbicides for effective weed control in raya crop.

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Stale seedbed techniques for management of weedy rice (*Oryza sativa f spontanea* L.) in direct seeded rice

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ABSTRACT

Weedy rice *(Oryza sativa f spontanea)* is a weedy form of cultivated rice which has recently emerged as a serious threat to the direct seeded *kharif* rice in Kerala. It competes aggressively with the crop, leading to drastic yield reduction besides contaminating the produce and the field. Considering the severity of the problem, field experiments were laid out to evolve an effective management strategy for weedy rice through integrated approach involving stale seedbed with herbicides and ploughing operations in a heavily weedy rice infested farmers' field. The treatments comprised of 4 different types of stale seed bed (SSB) technique, *viz.* SSB with and without stimulatory rice crop and destruction with a total weed killer *viz.* glyphosate or paraquat followed by dry or wet ploughing. The studies revealed that sowing of rice seeds have no significant influence in stimulating germination of weedy rice. In general, stale seedbed treatments resulted in reduction in weedy rice plant density to the tune of 39.83 % to 63.72% during first year and 58.27 to 76.99% during second year. Stale seedbed coupled with glyphosate application followed by wet ploughing the field and wet seeding recorded the lowest weedy rice population and highest rice yields of 1.70 and 1.71 t/ha during both the years. Yield loss under unweeded situation measured by weed index was 75.60 with a BCR of 0.87 during first year and yield loss touched its peak during second year with a BCR of 0.70 which indicated the harmful effect of seed bank accumulated during previous year in unweeded areas. Stale seedbed with glyphosate application followed by wet ploughing under continuous submergence could be recommended as an effective preventive management strategy for weedy rice management in direct seeded rice.

Key words: Direct seeded rice, glyphosate, stale seedbed, weedy rice, wet ploughing.

As the resources needed for flooded, transplanted rice cultivation become scarce, there is increased economic pressure to shift to DSR (direct seeded rice) which refers to the establishment of rice crop through seeds directly sown in the field. The dry direct sown system of rice cultivation is a unique and extensively adopted system of rice cultivation in 20% rice growing area of our country and in Kerala, it constitutes more than 60% of the area under rice during *Kharif* (Anitha *et al.*, 2009). In areas where DSR become the dominant establishment method, weedy rice is a primary emerging constraint to rice production (Chauhan *et al.*, 2013). In Kerala, rice cultivation is seriously constrained with the spread of weedy rice in major rice growing tracts and the infestation is so severe that in most of the cases the rice crop has to be replaced for a while by another crop which is not at all feasible in the present scenario of acute labour shortage. Weedy rice *(Oryza sativa f. spontanea)* has been identified as one of the most problematic weed in the 21st century which seriously affects rice yields (Varshney and Tiwari, 2008). Evolved largely by natural hybridization between wild and cultivated rice, it became dominant when farmers have switched to direct seeding due to labour shortage and high cost of labour (Rathore *et al.*, 2013). It competes aggressively with the crop leading to drastic yield reduction in addition to contaminating the harvest and field. With diverse biotypes it has already infested large rice growing areas across the globe and major rice tracts of Kerala (Abraham *et al.*, 2012). Weedy rice has competitive advantage over cultivated rice as it grows taller and faster, tillers profusely, flowers much earlier than cultivated rice and competes with cultivated rice for nutrients, light and space.

Weedy rice cannot be differentiated from cultivated rice in vegetative stages and by the time panicle emerges the damage is already done. Important traits for the success of weedy rice are early shattering of the grain and variable seed dormancy (Azmi and Karim , 2008). The spread has been favoured by the sowing of rice seeds procured from external agencies that contain grains of weedy rice. In Kerala, heavy infestation in the recent years has caused a reduction in the yield by 30 to 60% (Abraham *et al.*, 2012) depending on severity of infestation (3 to 10 mature plants of weedy rice per sq. m). The main problem of weedy rice is its grain shattering nature as and when it matures leading to persistent incidence of seeds in rice field contributing to weed seed bank which spread through water channels. Hence, an integrated management strategy that reduces the source of weedy rice need to be developed for long term control. In the absence of selective herbicides to control the weedy rice plants, managing weed seedbank by stale seedbed techniques is an alternate option. Stale or false seedbed technique is a preventive method of weed management which involves the soil preparation of a seedbed to promote germination of weeds a number of days or weeks before the actual sowing or planting of the crop, thus depleting the seed bank in the surface layer of soil and reducing subsequent emergence. While preparing false seedbed, sowing rice seeds for stimulating germination of weedy rice was a common practice among farmers which require validation. The efficacies of tillage operations that are usually performed after SSB also need to be assessed so as to formulate an integrated package. In this backdrop, the present study was undertaken with the main objective of evaluating the feasibility of an integrated package comprising stale seedbed coupled with total weed killers followed by wet and dry ploughing for weedy rice management in direct-seeded rice.

MATERIALS AND METHODS

The field experiment was undertaken in a heavily weedy rice infested area in farmers' field during *kharif* season of 2011-12 and 2012-13. The area experiences a warm humid tropical climate. The soil tested was silty clay in texture, acidic in reaction (5.3), organic carbon (0.35%), available P(28.1 kg/ha) and available K (204.5 kg/ha). The experiment was laid out in randomised block design with 10 treatments replicated thrice. The treatments comprised of 4 different types of stale seedbed (SSB) technique with and without a stimulatory rice crop and destruction with a total weed killer (either glyphosate or paraquat) followed by dry or wet tillage. The treatment details are provided in Table 1. The crop establishment after stale seedbed was with dry and wet ploughing followed by dry or wet sowing. Use of stimulatory rice crop was included under the belief of farmers that presence of rice seeds in the field stimulates germination of

Table 1. Treatment details

T_1	SSB with stimulatory rice crop and destruction with glyphosate fb dry ploughing
T_2	SSB with stimulatory rice crop and destruction with glyphosate fb wet ploughing
T_3	SSB with stimulatory rice crop and destruction with paraquat fb dry ploughing
T_4	SSB with stimulatory rice crop and destruction with paraquat fb wet ploughing
T_5	SSB without stimulatory rice crop and destruction with glyphosate fb dry ploughing
T_6	SSB without stimulatory rice crop and destruction with glyphosate fb wet ploughing
T_7	SSB without stimulatory rice crop and destruction with paraquat fb dry ploughing
T_8	SSB without stimulatory rice crop and destruction with paraquat fb wet ploughing
T_9	SSB without herbicide fb wet ploughing
T_{10}	Unweeded control

weedy rice seeds. The land was ploughed after the receipt of summer showers and rice seeds of variety 'Jyothi' sown @ 10 kg/ha under optimum moisture condition and left idle to stimulate germination of seeds of weedy rice in particular and other weeds. After 15 days, all the germinated flushes were killed by a nonselective herbicide glyphosate @ 1.0 kg/ha or paraquat @ 0.8 kg/ha using a knapsack sprayer fitted with floodjet nozzle with water as carrier at 300 l/ha. Later, the herbicide applied plots were subjected to wet or dry ploughing. In dry ploughing the soil was tilled again and seeds of Jyothi were dry sown by broad casting. In wet ploughing, the soil was tilled once the field got flooded with monsoon showers and Jyothi seeds were broad casted. A uniform dose of 90 kg N, 45 kg P_2O_5 and 45 kg K_2O were applied in the form of urea, rajphos and muriate of potash in each experimental plot. One third of nitrogen and potassium and full dose of phosphorus were applied as basal dose and remaining amount of nitrogen and potassium were applied in two equal splits at tillering and panicle initiation stages. Observations on density of weedy rice plants were recorded after flowering from each plot randomly using 0.25 m^2 quadrat. The yield data was also recorded and subjected to statistical analysis.

RESULTS AND DISCUSSION

Effect of stale seedbed treatments on weedy rice population

The results of the study revealed that sowing of rice seeds have no significant influence in stimulating germination of weedy rice which could be inferred from the similar weedy rice plant density observed in plots where stimulatory rice crop was not sown. Hence the farmers' belief of stimulated germination of weedy rice in presence of rice seeds remained insignificant. All the SSB treatments were effective in bringing down the weedy rice plant density as evident from the higher values of density recorded in unweeded control (37.66 and 46.33 m^{-2}) during both the years. Stale seedbed technique was aimed at reducing weedy rice infestation in the same season in which it was applied thereby gradually lowering its soil seed bank. State seed bed (SSB) treatments with weed killers resulted in reduction in weedy rice plant density to the tune of 39.83% to 63.72% during first year and 58.27 to 76.99% during second year. These results were in agreement with the findings of Jose *et al.*, (2012) and Chen (2001) where they observed that SSB was an efficient means to reduce seed bank of weedy rice. Sindhu *et al.*, (2011) have also confirmed the effectiveness of stale seedbed technique in reducing the weed population by depleting the soil weed reserves in rice fields. Based upon the wide range of known ecotypic germination behavior and the quantitative genetic nature of the dormancy, it is likely that a number of environmental and genetic factors contributing to dormancy of weedy rice remain to be characterized (Ziska *et al.*, 2014). On comparing the effectiveness of total killers for weed control, glyphosate @ 1kg/ha was more effective in reducing weed population in comparison to paraquat treatment. This may be because of the systemic action of glyphosate in effectively controlling the weed plants emerged after stale seedbed. It was evident from the study that dry ploughing operations after stale seedbed caused increase in weedy rice population per unit area during both the years. This was because of the fact that soil disturbance by tillage brought more of weedy rice seeds to the surface breaking its seed dormancy and ensured uniform germination of weeds from soil surface.

Effect of stale seedbed treatments on rice yield

Regarding yield of rice, the highest yields of 1.70 and 1.71 t/ha were recorded in SSB with glyphosate application fb wet ploughing and seeding during both the years. It also recorded the lowest weedy rice population during both the years which indicated the correlation between crop weed competition and rice yield. Wet ploughing fared better compared to dry ploughing because it prevented further germination under continuous submergence. On the contrary, dry ploughing operations took the buried seeds to the top soil and promoted further germination. Stale seedbed without chemical weeding fb wet tillage recorded a yield of 1.44 and 1.45 t/ha which indicated the favourable effect of wet tillage in reducing weedy rice

Table 2. Effect of SSB and tillage practices on weedy rice population and yield in direct seeded rice

Treatments	2011-12				2012-13			
	No. of weedy rice plants/m^2	No. of weedy rice plants/m^2	% reduction in weedy rice population	% reduction in weedy rice population	Yield (t/ha)	Yield (t/ha)	Weed Index	Weed Index
T_1	17.33	13.66	53.78	70.51	1.43	1.48	18.88	15.54
T_2	13.66	10.66	63.72	76.99	1.70	1.71	-30.58	-31.57
T_3	22.33	18.33	40.70	60.43	1.18	1.17	12.71	16.23
T_4	18.33	15.33	51.32	66.91	1.33	1.36	-11.27	-2.20
T_5	21.66	17.67	42.48	61.86	1.26	1.33	5.55	25.56
T_6	14.33	10.66	61.94	76.99	1.63	1.67	-22.69	-20.35
T_7	22.66	19.33	39.83	58.27	1.27	1.33	28.34	12.78
T_8	20.33	17.33	46.01	62.59	1.45	1.50	-12.41	-3.33
T_9	25.07	19.66	33.43	57.56	1.44	1.45	0.69	17.93
T10	37.66	46.33	00.00	00.00	0.82	0.17	75.60	905.88
SEm(±)	6.12	7.89	-	-	0.04	0.03	-	-
CD (P=0.05)	2.02	2.29	-	-	0.12	0.09	-	-

Table 3. Effect of SSB and tillage practices on economics of direct seeded rice

Treatments	Cost of cultivation (Rs/ha)	Gross returns(Rs/ha)		BCR	
		2011-12	2012-13	2011-12	2012-13
T_1	20310	25740	25160	1.26	1.23
T_2	20310	30600	29070	1.43	1.36
T_3	20810	21240	19890	1.02	1.05
T_4	21810	23940	23120	1.09	1.06
T_5	20000	22680	22610	1.13	1.13
T_6	21000	29340	28390	1.39	1.35
T_7	20000	22860	22610	1.14	1.13
T_8	21599	26100	25500	1.20	1.18
T_9	19000	25920	24650	1.36	1.29
T_{10}	16850	14760	11900	0.87	0.70

germination. Stale seedbed with glyphosate followed by dry ploughing significantly enhanced the weedy rice population by bringing more seeds to the surface layer from the weed seed bank. This was in conformity with the findings of Jose *et al.,* (2012) who reported that stale seed bed operations took the buried seeds to the top soil for promoting germination of weedy rice seeds. Various authors suggested that integrating cultural measures with weed control tactics can have a broader impact on weeds (Alsaadawi *et al.,* 2011). The weed indices gave the extent of crop loss due to weedy rice competition taking the yield from the treatment which recorded the maximum yield. Yield loss was maximum under unweeded plots with a BCR of 0.87 during first year and during second year yield loss touched its peak (BCR of 0.70) which indicated the harmful effect of seed bank accumulated during previous year in unweeded areas. This observation clearly necessitated the need for preventing the buildup of seed bank in soil by preventive methods and the correlation between intensity of weed competition and crop loss. Also it corroborated the reports of Chauhan *et. al.,* (2013) that weedy rice is among the most prevalent and troublesome weed species wherever DSR is the primary means of rice establishment

For tropically grown rice under traditional flooded conditions, average yield losses from weed competition are around 35% (Oerke and Dehne, 2004) in contrast, weed-induced yield losses can be as high as 100% under DSR conditions (Rao *et al.*, 2007). The yield data recorded in weedy check plots during second year (0.17 t/ha) under direct seeding clearly indicated the effect of method of establishment in buildup of weedy rice population over years. Hence implementation of DSR will represent a historical paradigm shift in weed-rice interactions and weed-induced losses, potentially threatening the long-term sustainability of rice production (Ziska *et al.*, 2014). As the acceptability of any management practice depends on economic viability, it could be inferred that stale seedbed with glyphosate application followed by wet ploughing under continuous submergence could be recommended as an effective preventive management strategy for weedy rice management in direct seeded rice.

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Effect of fungicides and phytoextracts on spore germination of *Alternaria burnsii*

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ABSTRACT

An experiment was conducted on cumin crop and the treatment set of fungicides and phytoextracts were tested for their inhibitory effect on spore germination of *Alternaria burnsii* causing cumin blight was performed in *in vitro* condition. In the laboratory screening of non systemic fungicides, mancozeb, zineb, ziram and chlorothalonil were found most effective in spore germination inhibition of *A. burnsii*. Among systemic fungicides, hexaconazole and tebuconazole were found most effective in the reduction of spore germination of blight pathogens. Turmeric rhizome, garlic clove and ginger rhizome extracts proved to be the best sources of plant origin for the inhibition of spore germination of blight pathogen.

Key words: Fungicides, Phytoextract, Cumin, Spore, Blight

Cumin crop is affected mainly with three important diseases *viz.*, blight *(Alternaria burnsii)*, wilt (*Fusarium oxysporum* f.sp. *cumini*) and powdery mildew *(Erysiphe polygoni)* (Dange, 1995). *A. burnsii* have pale olive green hypha or hyphae are 1.7 to 5.8 micrometer in diameter. The solitary or fasciculate, erect, simple or branched, straight or beat geniculate conidiophores, sometimes with a single terminal scar, are 3 to 5 celled (rarely 8 celled on the host) and measure 15-52 µm × 1.9-3.7 µm. The obovate, occasionally obclavate, olive-brown conidia, borne singly on the host but in chains of 2 to 10 in culture, are furnished with 1 to 9, mostly 3 to 5 transverse septa, taper towards the apex which may be elongated in to a beak often as long as the spore and measure 13.8-55.1 × 6.9-25.2 µm without the beak and 23-118.9 × 7 to 29.9 µm with it. (Uppal, *et al.*, 1938). Cumin is susceptible to blight after flowering. In initial stage of the disease, ash-coloured spots or lesions are observed on the leaf and branches. Under wet and warm conditions infection rapidly spreads to the stem and blossoms and in severe conditions, the whole plant dries-up and become black in colour as if it burnt. In cases of very severe infection, there may not be any seed production. Even if seeds are produced, they are shriveled, dark-coloured, light in weight and usually non-viable (Gemawat and Prasad, 1972). In India, the major cumin growing states Gujarat and Rajasthan, together accounts for more than 70 per cent of total country's production (Anonymous, 2010-11). The area under cumin cultivation in India is about 858900 ha with annual production of 513850 tonnes (Anonymous, 2013-14). Chemical control measures have been tested and found effective in the control of diseases (Dange, *et al.*, 2005). Use of pesticides of plant origin have been suggested by some workers as alternative to synthetic chemicals in order to counter the potential hazardous effect on the environment associated with the use of synthetic chemicals (Babu, *et al.*, 2001). Therefore, in the present investigation, inhibition spore germination of cumin blight fungus, *Alternaria burnsii*, exposed to different concentrations of fungicides and plant extracts of plants were studied.

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MATERIALS AND METHODS

A lab experiment was conducted during 2012-13 at P.G. laboratory, Department of Plant Pathology, College of Agriculture, JAU, Junagadh. Total 14 fungicides were tested in two groups *i.e.* non-systemic and systemic and nine *phytoextracts*, replicated four times in a completely randomized design. Slide germination technique was employed with different fungicides and phytoextracts, to study their efficacy on *A. burnsii*, spore germination inhibition. Double strength than required concentration for fungicides and phytoextracts were obtained by dilution technique in sterilized distilled water. Spore suspension was prepared in sterilized distilled water separately. Spore germination of *A. burnsii* was obtained by following procedure.

Preparation of spore suspension : Spores were collected from 10 day old culture of *A. burnsii* and respective suspensions prepared in 10 ml. of sterilized water. The suspension was then examined under the microscope (10x) and spore were adjusted to about 30 spores per one optical field.

Preparation of fungicidal and phytoextracts solution : Non systemic fungicides (mancozeb 75 WP, copper hydroxide 77 WP, thiram 75 SD, chlorothaonil 75 WP, zineb 75 WP, copper oxychloride 50 WP and ziram 28 SC) were tested at 500 and 1000 ppm concentrations, while systemic fungicides (carbendazim 50 WP, thiophanate methyl 70 WP, picoxystrobium 25 EC, dimethormorph 50 WP, hexaconazole 5 EC, propiconazole 25 EC and tebuconazole 25.9 EC) were tested at 250 and 500 ppm concentrations. Nine locally available plants (*Allium sativum* L. (Garlic), *Zingiber officinale Rosc.* (Ginger), *Ocimum sanctum* L. (Tulsi), *Lantana camera* L. (Lantana), *Jetropha curcas* L. (Jatropha), *Adhatoda vasica Ness.* (Ardusi), *Allium cepa* L. (Onion), *Azadirachta indica* (Neem) and *Curcuma longa* L. (Turmeric)) were used for their evaluation at 5 and 10 per cent concentrations against the pathogens. Fresh leaves, rhizomes or cloves of respective plants were first washed with tap water and then with sterilized water. Each sample was then homogenized in sterilized distilled water at the rate of 1 ml/g of tissues (1:1 V/W) with a pestle and mortar and filtered through fine muslin cloth. The filtrate was centrifuged at 5000 rpm for 20 minutes and the supernatant was filtered with sterilized sintered funnel (pore size 1-2 microns), which formed the standard plant extract solution (100%).

Preparation of the slides : One drop of each fungicide and phytoextract was placed separately on a glass slide and one drop of spore suspension was placed exactly on this respective drop so that required concentration was obtained in each of the treatment. The experiments were replicated four times. These slides were kept in Petri plates lined with moist blotting paper and incubated at room temperature. Observations of germinated spores were recorded at interval of 24, 48 hrs and 72 hrs, per cent spore germination and spore germination inhibition were worked out as per following formula (Vincent, 1947).

$$PG = \frac{A}{B} \times 100$$

Where, PG = Per cent germination,

A = Number of conidia germinated,

B = Total number of conidia examined

$$I = \frac{C - T}{C} \times 100$$

Where, I = Per cent inhibition,

C = Number of germinated spores, in control

T = Number of germinated spores, in treatment

RESULTS AND DISCUSSION

Effect of non systemic fungicides on spore germination of A. burnsii

All non systemic fungicides significantly reduced spore germination after 24, 48 and 72 hrs of incubation. After 72 hrs of incubation, only, 12.42 and 10.56 per cent spore germination was recorded in mancozeb at 500 and 1000 ppm, respectively. The mean germination of three durations in mancozeb was recorded 11.16 and 9.44 per cent at 500 and 1000 ppm, respectively as against 79.66 per cent in control (Table 1). The other fungicides *viz.* zineb, ziram and chlorothalonil were also found effective and reported 83.19, 83.61 and 79.07 mean per cent germination at 500 ppm and 85.11, 86.86 and 83.75 at 1000 ppm concentration, respectively. The per cent inhibition under the fungicides ranged from 88.14 (Mancozeb) to 71.29 (Copper hydroxide) at higher concentrations. Among the non systemic fungicides, mancozeb was found most effective in spore germination inhibition of *A. burnsii.* These results match with the investigation made by Pipliya and Jadeja (2008) where mancozeb was found most effective in spore germination inhibition of different isolates of *A. burnsii.* Mancozeb was also reported most effective in spore germination inhibition of *Alternaria* spp. (Satish *et al.*, 2004).

Effect of systemic fungicides on spore germination of A. burnsii

All systemic fungicides under test significantly reduced spore germination after 24, 48 and 72 hrs of incubation. The lowest mean spore germination of 14.98 and 12.70 per cent were recorded in hexaconazole followed by tebuconazole (16.39 and 13.41 per cent) at 250 and 500 ppm, respectively (Table 2). Similar trend was also noted in case of propiconazole where spore germination was 17.44 and 14.99 per cent in 250 and 500 ppm, respectively. Minimum mean spore germination inhibition was recorded in carbendazim (47.81 % and 52.25 %) in respective both the concentration as against more than 80 per cent in hexaconazole, tebuconazole and propiconazole at 500 ppm concentration. The spore germination inhibition in these fungicides at 250 ppm concentration was 81.50, 79.76 and 78.46 per cent respectively. Among the systemic group trizole fungicides *viz.* hexaconazole, tebuconazole and propiconazole are reported highly effective in spore germination inhibition of *A. burnsii.* These observations are supported

Table 1. Spore germination of *A. burnsii* at dfferent concentrations of non systemic fungicides.

Sl. No.	Fungicide	Concentration (ppm)	Per cent spore germination after*			Mean (pooled)	Per cent inhibition over control
			24 hrs	48 hrs	72 hrs		
1	Mancozeb 75 WP	500	9.89	11.17	12.42	11.16	85.99
		1000	8.20	9.56	10.56	9.44	88.14
2	Copper hydroxide 77 WP	500	23.56	25.25	27.12	25.31	68.82
		1000	22.25	22.56	23.81	22.87	71.29
3	Thiram 75 WP	500	17.34	18.00	19.06	18.31	77.01
		1000	15.81	16.83	17.39	16.67	79.07
4	Chlorothalonil 75 WP	500	13.67	14.42	16.34	14.81	81.40
		1000	12.42	12.50	13.92	12.94	83.75
5	Zineb 75 WP	500	10.25	13.75	15.17	13.05	83.61
		1000	9.34	10.39	11.67	10.46	86.86
6	Copper oxychloride 50 WP	500	23.17	23.92	25.75	24.28	69.52
		1000	21.83	22.00	23.50	22.44	71.83
7	Ziram 28 SC	500	12.59	13.31	14.09	13.39	83.19
		1000	11.25	11.92	12.42	11.86	85.11
8	Control	-	71.00	80.00	88.00	79.66	
	S. Em. ±		0.27	0.27	0.30	1.32	-
	CD at 5%		0.76	0.77	0.85	3.80	-
	CV %		3.46	3.18	3.26	13.39	-

* Mean of four replications

Table 2. Spore germination of *A. burnsii* at different concentrations of systemic fungicides

Sl. No.	Fungicide	Concentration (ppm)	Per cent spore germination after*			Mean (pooled)	Per cent inhibition over control
			24 hrs	48 hrs	72 hrs		
1	Carbendazim 50 WP	250	39.92	42.34	44.56	42.27	47.81
		500	37.31	38.89	39.81	38.67	52.25
2	Thiophanate meyhyl 70 WP	250	37.89	40.06	41.89	39.94	50.69
		500	35.75	37.31	37.97	37.01	54.30
3	Picoxystrobium 25 EC	250	32.25	35.59	36.31	34.71	57.14
		500	30.75	32.39	32.70	31.94	60.56
4	Dimethormorph 50 WP	250	36.00	38.31	39.14	37.81	53.32
		500	34.09	35.25	36.17	34.17	57.81
5	Hexaconazole 5 EC	250	13.86	14.84	16.25	14.98	81.50
		500	11.84	12.95	13.31	12.70	84.32
6	Propiconazole 25 EC	250	16.89	17.39	18.06	17.44	78.46
		500	13.72	15.31	15.95	14.99	81.49
7	Tebuconazole 25.9 EC	250	15.84	16.14	17.20	16.39	79.76
		500	12.75	13.39	14.09	13.41	83.44
8	Control	-	72.00	83.00	88.00	81.00	
	S. Em. ±		0.35	0.37	0.27	1.30	-
	CD at 5%		1.06	1.05	0.77	3.72	-
	CV %		3.12	2.99	2.13	9.21	-

* Mean of four replications

Table 3. Spore germination of *A. burnsii* under two concentrations of phytoextracts.

Sl. No.	Phytoextract (common name)	Concentration (ppm)	Per cent spore germination after*			Mean (pooled)	Per cent inhibition over control
			24 hrs	48 hrs	72 hrs		
1	*Allium sativum* L. (Garlic)	5	30.50	31.50	33.75	31.91	60.11
		10	27.06	28.42	30.42	28.63	64.21
2	*Zingiber officinale Rosc.* (Ginger)	5	32.50	33.25	34.59	33.44	58.20
		10	30.06	31.08	33.42	31.18	60.60
3	*Ocimum sanctum* L. (Tulsi)	5	39.42	40.44	41.98	40.61	49.23
		10	37.00	38.00	39.06	38.02	52.47
4	*Lantana camera* L. (Lantana)	5	43.42	44.06	46.25	44.57	44.28
		10	41.00	42.09	43.59	42.22	47.22
5	*Jetropha curcas* L. (Jatropha)	5	46.45	47.28	48.70	47.47	40.66
		10	43.00	44.00	45.25	44.08	44.90
6	*Adhatoda vasica Ness.* (Ardusi)	5	50.00	51.00	52.34	51.11	36.11
		10	47.09	48.06	49.14	48.09	39.88
7	*Allium cepa* L. (Onion)	5	37.06	37.75	38.42	37.74	52.82
		10	34.89	35.39	36.14	35.47	55.66
8	*Azadirachta indica* L. (Neem)	5	36.50	37.25	38.14	37.29	53.38
		10	32.50	33.09	34.09	33.22	58.47
9	*Curcuma longa* L. (Turmeric)	5	33.64	34.14	34.92	34.23	57.21
		10	30.50	31.25	32.25	31.33	60.83
10	Control	-	73.00	79.00	88.00	80.00	
	S. Em. ±		0.28	0.26	0.30	1.06	-
	CD at 5%		0.78	0.28	0.86	3.0	-
	CV %		1.91	1.79	1.94	6.16	-

* Mean of four replications

by Pipliya and Jadeja (2008). They reported hexaconazole as most effective systemic fungicide for the inhibition of *A. burnsii.*

Effect of different phytoextracts on spore germination of A. burnsii

Effect of nine different phytoextracts on the spore germination of test fungus was evaluated at 5 and 10 per cent concentrations by slide spore germination technique. The results presented (Table 3) revealed that all the phytoextracts significantly reduced spore germination of *A.burnsii* with inhibition variation ranged between 60.11 to 64.21 per cent (garlic) and 36.11 to 39.88 per cent (ardusi) at lower (5 %) and higher (10%) concentration, respectively. Minimum mean spore germination was obtained in garlic 31.91 and 28.63 at 5 and 10 per cent concentration, respectively, which closely followed by ginger (33.44% and 31.52%) and turmeric (34.23% and 31.23%). The rest of phytoextracts were found moderately effective. Within phytoextracts, the spore germination significantly differed with narrow range. Higher concentration of all the phytoextracts were more effective as compared to their lower level. The antifungal properties of naturally occurring substances in plant species showed that garlic clove extract was excellent source as spore germination inhibitior of *A. burnsii.* Almost similar results have been reported by Karade and Sawant (1999). They found that 10% extract of *A. sativum* (garlic) completely inhibited spore germination of the *A. alternata.* In other study Jha *et al.*, (2004) reported 100% sporulation inhibition of Helminthosporium maydis with garlic and onion.

CONCLUSION

The effect of fungicides, tested for their inhibitory effect on spore germination of *A. burnsii.* The non systemic fungicides *viz.* mancozeb, zineb, ziram and chlorothalonil were found most effective against *A. burnsii,* where as among systemic fungicides hexaconazole and tebuconazole were highly effective in the reduction of spore germination of *A. burnsii.* Different phytoextracts were also tested against blight fungus under in vitro condition. Minimum spore germination was found with garlic followed by ginger, turmeric, neem, onion, tulsi, lantana, jatropha and ardusi, respectively in case of blight fungus.

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Investigations on the field bio-efficacy of some newer insecticides against insect pests of brinjal (*Solanum melongena* L.)

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Abstract

A field trial was conducted to investigate the field bio efficacy of some newer insecticides against insect pests of brinjal at horticultural farm Rajasthan College of Agriculture, Udaipur during August-December 2008. Spirotetramat + imidacloprid @ 75 + 75 g a.i./ha was found most effective for the control of jassids and white flies as it accounted more than 76.11 per cent control, even after fourteen days of spraying. Imidacloprid 200 SL @ 75 g a.i./ha was found better than other treatments in reducing jassids and white flies population which was statistically at par with spirotetramat + imidacloprid @ 60 + 60 g a.i./ha. Spirotetramat 150 SC @ 75 g a.i./ha was adjudged most superior for the control of brinjal shoot and fruit borer. Dicofol and imidacloprid proved to be the least effective and flubendiamide gave moderate control of shoot and fruit borer which was at par with beta-cyfluthrin. Ready mixture of spirotetramat + imidacloprid and all the other insecticides did not show any photo toxic effect on brinjal plants.

Key words: Jassid, shoot & fruit Borer, white fly, meteorological week.

Brinjal or eggplant, *Solanum melongena* (L.) is one of the most popular and principal vegetable crop grown in India. It can be grown in almost all parts of India except higher altitudes all around the year. In India, the total area under cultivation of brinjal during 2006 was 5, 83,842 ha and production was 98, 02,398 tones (FAO). In Rajasthan brinjal is grown throughout the year in almost all districts, however, Jaipur, Kota, Sriganganagar and Jodhpur are main growing regions. The major insect pests of brinjal affecting the yield and quality are shoot and fruit borer (*Leucinodes orbonalis* Guenee), jassid (*Amrasca biguttula biguttula* Ishida), white fly (*Bemisia tabaci* Genn.) and red spider mite (*Tetranychus* spp.), stem borer (*Euzophera perticella* Rag.), hadda beetle (*Epilachna* spp.) and lace wing bug (*Urentius centis* Distant). Jassids, besides sucking the cell sap from the leaves and tender parts also act as vectors of the Mycoplasma like Organisms (MLOs) which are the causal organism of the disease little leaf of brinjal (Singh 1996). For managing the population of pests of brinjal, different methods have been used, but to keep the population below the economic injury level, the use of insecticides seems to be the only remedy. Many recommendations over the use of insecticides are in vogue and their regular use has made the insect resistant towards them, besides disrupting the ecosystem. Since, brinjal is a high value crop so chemical control is generally practiced for higher production. Indiscriminate use of conventional old pesticides have lead to many problems like toxic residues causing health hazards, phytotoxic symptoms like burning of leaves, wilting, chlorosis on plant resulting in reduction of yield.

Materials and Methods

During August to December 2008, a field experiment was conducted to investigate the field bio efficacy of some newer insecticides against insect pests of brinjal (*Solanum melongena* L.), in back yard fields of horticulture department, Rajasthan College of Agriculture, Udaipur.

Lay out of experiment : To investigate the field bio efficacy of some newer insecticides against insect pests of brinjal, the experiment was laid out in Randomized block design uniformly sized plots measuring 3 × 4.5 m (13.5 sq. m.) replicated three times. The variety BR-116 was grown with row to row and plant to plant distance was maintained at 60 cm and 45 cm respectively, in each of the three plots. Five plants/plot were selected and tagged so as to record the observations on these plants throughout the experimental period.

Three different doses of spirotetramat 120 + imidacloprid 120-24 SC mixture, one dose of spiroteramat 150 SC, one dose from each of, imidacloprid 200 SL, dicofol 18.5 EC, endosufan 35 EC, flubediamide 48 SC, beta cyfluthrin 2.5 SC in relation to untreated control (water spray) as standard check against insect pests of brinjal were evaluated.

Thus there were 10 treatments in all including the control and each treatment was replicated three times. In all, three sprays were given as and when required according to the degree of incidence and damage observed.

Observations : Pre-treatment population of insect pests was recorded according to their specific technique 24 hours before the scheduled spray. Post spray population was recorded on 1, 7 and 14 days after spraying.

Sampling techniques : The appropriate sampling techniques were adopted for the estimation of population of different insect pests as given below:

(1) *Jassids* : The method suggested by Rawat and Sahu (1973) was adopted for estimating the population of jassids, three leaves; one, each from the basal, middle and upper portion were selected from the five tagged plants in each plot. The population was estimated by gently holding the leaf between the halves of a Petri plate and then counting adults and the nymphs within the Petri plate. However, in case of the nymphal stage, direct counting of the population was done with help of magnifying lens.

(2) *White flies* : To estimate the population of white flies, the number of insects on five tagged plants from each replicated plots, were counted. Three leaves, one each from the upper, middle and lower portion of each of tagged plants were randomly selected to determine the population. The base of leaf was held between finger and thumb and twisted gently, nymphs and adults were counted quickly and carefully with least disturbance.

(3) *Shoot and fruit borer* : The number and weight of healthy and damaged fruits per plot per picking in each replication was recorded from the plots specified for the purpose of recording population density.

Statistical analysis : Efficacy of different treatments in controlling the insect pests was analyzed by analysis of variance.

Table 1. Details of the treatments

Treatments	Doses g a.i./ha
T_1: Untreated control (water spray only)	---
T_2: Spirotetramat 120 + Imidacloprid 120-240 SC	45 + 45
T_3: Spirotetramat 120 + Imidacloprid 120-240 SC	60 + 60
T_4: Spirotetramat 120 + Imidacloprid 120-240 SC	75 + 75
T_5: Spirotetramat 150 SC	75
T_6: Imidacloprid 200 SL	75
T_7: Dicofol 18.5 EC	185
T_8: Endosulfan 35 EC	437.5
T_9: Flubendiamide 48 SC	60
T_{10}: Beta cyfluthrin 2.5 SC	18

$$\% \text{ reduction in population} = 100 \times \left[1 - \frac{T_a \times C_b}{T_b \times C_a}\right]$$

Where,

T_a = Number of insects after treatment.

T_b = Number of insects before treatment.

C_a = Number of insects in untreated check after treatment.

C_b = Number of insects in untreated check before treatment.

The reduction percentage figures were transformed into arc sine values and subjected to analysis of variance.

RESULTS AND DISCUSSION

The jassid, Amrasca biguttula biguttula (Ishida)

The present results indicated that maximum reduction was observed on 14th day after treatment in all the three sprays. Amongst the different insecticidal treatments investigated against jassids, spirotetramat + imidacloprid @ 75 g + 75 g a.i./ha caused maximum reduction which was significantly superior over other treatments. Thus spirotetramat + imidacloprid @ 75 g + 75 g a.i./ha was an optimum dose for controlling the population of jassids. The present results are in conformity with the results of Duvars ch *et al.*, (2008) who reported that spirotetramat + imidacloprid at higher doses (120 and 144 g a.i./ha, applied with addition of 0.25 per cent of methylated soya oil reduced the leaf hopper population significantly on cotton crop.

Among other treatments, imidacloprid 200 SL @ 75 g a.i./ha gave the moderate results and it was at par with spirotetramat + imidacloprid @ 60 g 60 g a.i./ha. Thus imidacloprid 200 SL @ 75 g a.i./ha is an optimum dose for controlling the population of jassids. However, the present results were in tune with the work of Satpathy and Rai (2001) who reported maximum control of *A. biguttul abiguttula* on okra by imidacloprid. The results were also found comparable to the view of Ameta and Sharma (2005) who adjudged imidacloprid 70 WS @ 35 g a.i./ha to be most effective amongst all the treatments investigated against jassids on cotton crop.

The whiteflies; Bemisia tabaci Gennadius

Among different treatments tested, spirotetramat + imidacloprid @ 75 + 75 g a.i./ha caused maximum reduction which was significantly superior over all other treatments followed by imidacloprid 200 SL @ 75 g a.i./ha which was at par with spirotetramat + imidacloprid @ 60 g 60 g a.i./ha. Thus spirotetramat + imidacloprid @ 75 + 75 g a.i./ha is an optimum dose for controlling white flies population. The findings are in agreement with report of AICCIP Annual Group Meeting of Entomological panel (2007-08) they presented that spirotetramat 15 % OD + imidacloprid 36 % (480 SC) @ 90 g + 270 g a.i./ha were found to be effective to reduce the population of aphids and mealy bugs in cotton crop.

Among remaining treatments, endosulfan @ 35 EC @ 437.5 g a.i./ha gave moderate results and proved significantly superior to other treatments however, it was at par with dicofol 18.5 EC @ 185 g a.i./ha @ 0.05 per cent and found effective against whiteflies and mites.

The shoot and fruit borer; Leucinodes orbonalis Guenee

The experimental findings proved spirotetramat 150 SC @ 75 g a.i./ha to be superior to all treatments. Spirotetramat 150 SC @ 75 g a.i./ha reduced the infestation level on fruits to 3.07 per cent on seven and then 7.43 per cent on fourteen days after third spray, when the per cent damage in untreated control were 42.44 and 45.41 per cent respectively. Further, it was found that spirotetramat + imidacloprid @ 75 + 75 g a.i. /ha reduced the per cent damage to 4.44 per cent after third spray. The present findings were agreeable to the findings of Kumar *et al.*, (2007) who reported spirotetramat 150 OD @ 75 g a.i./ha as most effective in reducing aphid population in cotton crop.

The second best treatment was flubendiamide 48 SC @ 60 g a.i./ha which reduced damage to 9.77 per cent on seventh day after the third spray and stood at par with beta cyfluthrin 2.5 SC @ 18 g a.i./ha (per cent damage 10.04). Thus beta cyfluthrin 2.5 SC @ 18 g a.i./ha was an

Table 2. Effect of different treatments against shoot and fruit borer on brinjal mean percent infestation on fruits on number and weight basis after II spray.

Treatments		Per cent fruits damage days after (Number basis)				Per cent fruits damage days after (Weight basis)		
		3	7	14		3	7	14
Untreated Control (Water spray)	---	28.36 (32.18)	31.89 (34.38)	36.45 (37.14)	----	28.81 (32.46)	32.15 (34.54)	36.78 (37.33)
Spirotetramat 120+ Imidacloprid 120-240 SC	45+45	19.78 (26.41)	17.26 (24.55)	25.48 (30.32)	45+45	19.95 (26.53)	17.48 (24.72)	25.89 (30.59)
Spirotetramat 120+ Imidacloprid 120-240 SC	60+60	13.91 (21.90)	11.97 (20.24)	20.67 (27.04)	60+60	14.32 (22.24)	12.34 (20.56)	21.08 (27.33)
Spirotetramat 120+ Imidacloprid 120-240 SC	75+75	10.11 (18.54)	9.09 (17.55)	17.15 (24.46)	75+75	10.48 (18.89)	9.67 (18.12)	17.56 (24.77)
Spirotetramat 150 SC	75	9.71 (18.15)	8.26 (16.70)	15.02 (22.81)	75	10.00 (18.43)	8.63 (17.08)	15.47 (23.16)
Imidacloprid 200 SL	75	23.15 (28.76)	22.19 (28.10)	29.41 (32.84)	75	23.59 (29.06)	22.67 (28.44)	29.82 (33.10)
Dicofol 18.5% EC	185	24.00 (29.33)	23.11 (28.74)	31.52 (34.15)	185	24.50 (29.67)	23.56 (29.04)	32.04 (34.47)
Endosulfan 35 EC	437.5	19.96 (26.54)	17.63 (24.82)	26.26 (30.83)	437.5	20.38 (26.83)	17.92 (25.05)	26.63 (31.07)
Flubendiamide 48 SC	60	15.63 (23.29)	13.30 (21.39)	22.67 (28.44)	60	16.09 (23.65)	13.56 (21.61)	22.93 (28.61)
Beta cyfluthrin 2.5 SC	18	14.78 (22.61)	12.52 (20.73)	21.89 (27.90)	18	15.19 (22.94)	12.78 (20.95)	22.19 (28.10)
Sem±		0.70	0.59	0.68		0.71	0.74	0.64
CD 5%		2.08	1.75	2.03		2.12	2.20	1.91

" Figures in parenthesis are angular transformed values

Table 3. Effect of different treatment against shoot and fruit borer on brinjal mean per cent Infestation on fruits on number and weight basis after III spray.

Treatments		Per cent fruits damage days after				Per cent fruits damage days after		
		3	7	14		3	7	14
Untreated Control (Water spray)	----	39.85 (39.15)	42.44 (40.65)	45.41 (42.36)	----	40.18 (39.34)	42.81 (40.87)	45.74 (42.55)
Spirotetramat 120+ Imidacloprid 120-240 SC	45+45	16.84 (24.23)	13.80 (21.81)	16.23 (23.75)	45+45	17.21 (24.51)	14.03 (22.00)	16.45 (23.93)
Spirotetramat 120+ Imidacloprid 120-240 SC	60+60	11.49 (19.81)	8.18 (16.62)	11.12 (19.48)	60+60	11.78 (20.07)	8.59 (17.04)	11.48 (19.81)
Spirotetramat 120+ Imidacloprid 120-240 SC	75+75	8.34 (16.78)	4.44 (12.17)	8.26 (16.71)	75+75	8.45 (16.90)	4.81 (12.67)	8.48 (16.93)
Spirotetramat 150 SC	75	7.16 (15.52)	3.07 (10.10)	7.43 (15.82)	75	7.31 (15.69)	3.44 (10.69)	7.65 (16.06)
Imidacloprid 200 SL	75	21.30 (27.49)	18.78 (25.68)	19.89 (26.49)	75	21.60 (27.69)	18.97 (25.82)	20.18 (26.70)
Dicofol 18.5% EC	185	22.78 (28.51)	20.10 (26.64)	20.74 (27.09)	185	23.37 (28.91)	20.41 (26.86)	21.11 (27.35)
Endosulfan 35 EC	437.5	18.89 (25.76)	15.07 (22.85)	17.05 (24.39)	437.5	19.23 (26.01)	15.33 (23.05)	17.27 (24.56)
Flubendiamide 48 SC	60	13.15 (21.26)	9.77 (18.22)	13.15 (21.26)	60	13.41 (21.48)	10.11 (18.54)	13.37 (21.45)
Beta cyfluthrin 2.5 SC	18	13.96 (21.94)	10.04 (18.47)	12.30 (20.53)	18	14.22 (22.16)	10.15 (18.58)	12.67 (20.85)
Sem±		0.77	0.74	0.59		0.63	0.72	0.70
CD 5%		2.30	2.40	1.76		1.87	2.15	2.07

* Figures in parenthesis are angular transformed values

Table 4. Efficacy of different treatments against jassids on brinjal.

Treatments	Doses g a.i./ha	Percent reduction in jassids population days after each spray								
		First spray			Second spray			Third spray		
		1st day	7th day	14th day	1st day	7th day	14th day	1st day	7th day	14th day
Untreated Control (Water spray)	–	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Spirotetramat 120+ Imidacloprid 120-240 SC	45+45	59.37 (50.40)	63.05 (52.56)	68.81 (56.05)	61.48 (51.64)	67.41 (55.19)	70.67 (57.21)	63.33 (52.73)	69.26 (56.33)	72.55 (58.41)
Spirotetramat 120+ Imidacloprid 120-240 SC	60+60	62.04 (51.96)	67.74 (55.39)	73.11 (58.76)	64.33 (53.33)	70.42 (57.05)	74.73 (59.82)	66.75 (54.79)	72.00 (58.05)	77.18 (61.46)
Spirotetramat 120+ Imidacloprid 120-240 SC	75+75	68.28 (55.72)	71.78 (57.91)	76.11 (60.74)	71.07 (57.46)	75.18 (60.12)	79.00 (62.73)	73.48 (59.00)	77.18 (61.46)	81.11 (64.24)
Spirotetramat 150 SC	75	37.19 (37.58)	40.33 (39.43)	42.96 (40.95)	40.74 (39.66)	43.33 (41.17)	46.27 (42.86)	45.07 (42.17)	47.66 (43.66)	49.40 (44.66)
Imidacloprid 200 SL	75	63.77 (52.99)	68.54 (55.88)	74.28 (59.52)	65.91 (54.28)	69.85 (56.70)	75.44 (60.29)	67.07 (54.98)	73.11 (58.76)	78.11 (62.10)
Dicofol 18.5% EC	185	43.52 (41.28)	45.26 (42.28)	47.40 (43.51)	46.45 (42.96)	49.65 (44.80)	50.77 (45.44)	48.77 (44.30)	50.74 (45.43)	68.52 (55.87)
Endosulfan 35 EC	437.5	44.55 (41.87)	46.22 (42.83)	48.12 (43.92)	47.58 (43.61)	50.01 (45.00)	51.74 (46.00)	49.40 (44.66)	51.89 (46.09)	69.07 (56.21)
Flubendiamide 48 SC	60	36.48 (37.16)	39.52 (38.95)	41.89 (40.33)	39.78 (39.10)	42.52 (40.70)	45.65 (42.51)	43.89 (41.49)	46.74 (43.13)	48.22 (43.98)
Beta cyfluthrin 2.5 SC	18	35.47 (36.56)	38.59 (38.41)	40.98 (39.81)	38.80 (38.53)	41.67 (40.21)	44.62 (41.91)	42.85 (40.89)	45.63 (42.49)	47.51 (43.57)
Sem±		0.50	0.62	0.47	0.45	0.50	0.53	0.38	0.50	0.45
CD5%		1.48	1.85	1.41	1.34	1.49	1.59	1.14	1.48	1.34

* Figures in parenthesis are angular transformed values

Table 5. Efficacy of different treatments against white fly on brinjal.

Treatments	Doses g a.i./ha	Percent reduction in white fly population days after each spray								
		First spray			Second spray			Third spray		
		1st day	7th day	14th day	1st day	7th day	14th day	1st day	7th day	14th day
Untreated Control (Water spray)	--	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Spirotetramat 120+ Imidacloprid 120-240 SC	45+45	55.10 (47.93)	58.00 (49.60)	63.13 (52.61)	57.15 (49.11)	62.08 (51.99)	66.85 (54.85)	63.63 (52.91)	68.81 (56.05)	70.03 (56.81)
Spirotetramat 120+ Imidacloprid 120-240 SC	60+60	58.92 (50.14)	62.96 (52.51)	67.54 (55.27)	60.92 (51.31)	67.73 (55.39)	69.52 (56.49)	66.98 (54.93)	71.00 (57.42)	74.85 (59.90)
Spirotetramat 120+ Imidacloprid 120-240 SC	75+75	63.07 (52.58)	67.91 (55.49)	72.73 (58.52)	65.26 (53.89)	70.28 (56.97)	74.61 (59.74)	70.74 (57.25)	75.02 (60.01)	79.00 (62.73)
Spirotetramat 150 SC	75	39.34 (38.84)	43.02 (40.99)	47.00 (43.28)	41.56 (40.14)	45.02 (42.14)	50.02 (45.01)	45.07 (42.17)	48.04 (43.87)	53.02 (46.73)
Imidacloprid 200 SL	75	59.07 (50.23)	63.83 (53.03)	68.40 (55.80)	61.37 (51.57)	68.15 (55.64)	70.73 (57.25)	67.76 (55.40)	72.11 (58.12)	75.51 (60.34)
Dicofol 18.5% EC	185	42.82 (40.87)	46.08 (42.75)	50.92 (45.53)	45.66 (42.51)	49.38 (44.64)	52.78 (46.59)	50.98 (45.56)	56.77 (48.89)	61.97 (51.93)
Endosulfan 35 EC	437.5	43.60 (41.32)	47.04 (43.30)	51.83 (46.05)	46.26 (42.85)	50.37 (45.21)	53.59 (47.06)	52.12 (46.22)	58.01 (49.61)	63.08 (52.58)
Flubendiamide 48 SC	60	38.78 (38.52)	41.97 (40.38)	45.89 (42.64)	40.59 (39.58)	43.99 (41.55)	48.93 (44.39)	43.99 (41.55)	46.96 (43.26)	51.97 (46.13)
Beta cyfluthrin 2.5 SC	18	37.91 (38.00)	40.98 (39.80)	44.90 (42.07)	39.48 (38.93)	42.96 (40.95)	47.99 (43.85)	42.89 (40.91)	45.89 (42.64)	50.94 (45.54)
Sem±		0.49	0.44	0.46	0.51	0.42	0.47	0.46	0.54	0.55
CD 5%		1.47	1.31	1.37	1.51	1.24	1.41	1.37	1.61	1.65

* Figures in parenthesis are angular transformed values

optimum dose to reduce the infestation of shoot and fruit borer. The findings were agreeable with the findings of Sinha and Gopal (2001) who found the reduction in damage to 17-24 and 11.32 per cent respectively at normal dose (12.5 g a.i/ha) and double the dose (25 g a.i./ha) as compared to 30.45 per cent in the control plots. Further, the results were also comparable to the results of Satpathy and Ray (2001) who reported beta-cylfluthrin to be the best treatment in controlling the fruit borer of okra *(Earias vitella)*. However, it was clear from the results that endosulfan lowered the infestation on fruits to a moderate level. Maximum reduction in infestation by the use of endosulfan was observed on fourteenth day after treatment(17.92 and 15.07 per cent) on fruits respectively in the second and third spray; whereas the per cent infestation on fruits in untreated control plots were 32.15 and 42.44 during the second and third spray respectively.

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Comparative behavior of input cost and output prices of selected crops of Gujarat

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ABSTRACT

An attempt has been made to compare the input cost and output prices of selected five major crops of Gujarat State *i.e.* paddy, bajra, cotton (LS), wheat and pigeon pea. The time series data on input cost and output prices were collected from the past reports of "scheme for creating a permanent machinery for studying the cost of cultivation/production of principal crops grown in Gujarat state" (2001 to 2010). The positive and significantly higher growth rate of output prices for all five major crops was observed. The result of the instability index for output prices was found to be low. The high growth and low instability index indicates sustainability in production of these crops, which is the prerequisite for the state. The trend in parity indices shows that the improvement in terms of trade was in favour of farmers in case of paddy, pigeon pea, bajra and cotton crops, which needs to be sustained, where as in case of wheat the parity indices was not much in favour of farmers during the last decade. This clearly indicates that the increase in prices received for output of wheat did not increase in proportion to the increase in prices paid for inputs used in its cultivation.

Key words: Input cost, output prices, compound growth rate, instability index, parity indices.

Agriculture plays a key role in the overall economic and social well- being of India. Despite significant structural changes both at the national and state levels, agriculture still remains the backbone of the economy. The sector therefore, deserves to be assigned its due importance in planning at state level too. Agricultural prices are important economic variables in a market economy. Price relationships have a significant influence on decisions relating to the type and volume or agricultural production activity. They provide a measure for reaching judgment on policy formulation and administrative and executive action. Parity prices measure incentives or disincentives for agricultural production, given competition from national, international or cross border trade. Parity prices inform us about the market incentives and/or disincentives for local production of food crops, cash crops and livestock-particularly for agricultural exports. Incentives for local production are important to analyze because they give an indication of likely food availability and farm income derived from export markets. Farm income is subsequently used by households to buy food and/or farm inputs in support of the next season's production. (Athur Mabiso, 2008). The idea of parity had both statistical and political origins (Black, 1942). If there had never been any statisticians collecting data on prices of farm and other commodities, "farm parity" would never have come about. The parity movement was merely the outward expression of the mal adjusted relationship between agriculture and the rest of society that developed at the end of world war I.

The price data acquires considerable importance as it is crucial for the purpose of decision making in the sphere of economic activities. Its collection and compilation, therefore, deserve attention no less than that given to obtaining information on other socio-economic characteristics. The systems to be adopted in the compilation of price statistics must, therefore, be meaningfully determined in relation to their end uses. Since the agricultural producer is both a seller of his produce as well as a buyer of agricultural production requisites, agricultural prices cover not only the prices received by farmers (output prices) but also the prices paid by farmers (input prices). The farmer is also, of course, a buyer of consumer goods for use in his own household. It is debatable whether agricultural output prices are consistent with input prices or not. Therefore, this study was planned to compare the input cost and output prices of selected major crops of Gujarat.

METHODOLOGY

To achieve the objectives of the study, time series data on input cost and output prices of five major selected crops paddy, bajra, cotton (LS), wheat and pigeon pea of Gujarat were collected from the past reports of "scheme for creating a permanent machinery for studying the cost of cultivation/production of principal crops grown in Gujarat state" (2001 to 2010). The data were compiled and analysed using standard statistical tools. The Compound Growth Rate (CGR) and instability index were calculated by using the following methods.

The CGR was calculated by fitting the exponential function given below :

$$Y = a\,b^t \qquad (1)$$

Where, Y = area/production/productivity

a = constant

b = regression co-efficient

t = time variable

Thus, natural log on both the sides of eq (1) was taken to convert it in to linear form.

$$\text{Log } Y = \log a + t \log b \qquad (2) \text{ and,}$$

CGR (%) was worked out using following formula :

$$\text{CGR (\%)} = (\text{antilog of } b - 1) \times 100$$

The significant CGRs were classified in two groups *i.e.* negative and positive CGR.

The simple co-efficient of variation (CV) often contains the trend component and thus over estimates the level of instability in time series data characterized by long-term trends. To overcome this problem, the Cuddy Della Valle index was used to correct the CV.

$$\text{Instability index (II)} = CV \times \sqrt{(1 - R^2)}$$

Where, CV = co-efficient of variation and

R^2 = co-efficient of determination from a time trend regression adjusted by the number of degrees of freedom.

The instability index was classified into two groups *i.e.* Small < 25% and large > 25%

The high growth and low instability are prerequisites for sustainable agricultural performance. Since the magnitude of growth and instability in crop production has serious implications for policy makers, the growth and level of instability in input costs and output prices of major crops of Gujarat were estimated. Raw price data were properly processed and got index numbers. Index numbers of prices received by farmers was studied over time which indicates the extent to which changes in the value of output or farm disposals are attributable to changes in prices. Similarly, index numbers of prices paid by farmers throw light on the contribution of prices to changes in the total expenses incurred by farmers. The ratio of the two indices gives agriculture's terms of trade with the rest of the economy, and can be useful in explaining the variations in farmers' prosperity from time to time (Acharya and Agarwal, 1984)

The parity indices was calculated to examine the equity between input costs and output prices, as determined by the percentage of ratio of index of prices received for output prices to the index of prices paid for inputs of crops.

Index of terms of trade (parity index)

$$\textbf{Parity Index} = \frac{\text{Index of prices received for farm products}}{\text{Index of prices paid for farm product}} \times 100$$

Thus, the parity index was determined by the percentage of ratio of index of price received for agricultural products to the index of prices paid for agricultural inputs (Kahlon, 1998).

Selection of Base Period

Agricultural production is generally affected by uncertain factors like rainfall and whether and, therefore, in subject to large fluctuations from year to year. It is, therefore, appropriate that the base period should be more broad based by taking an average of a number of years coinciding with the agricultural cycle at the all India level which is considered to be generally of three years (Kahlon, 1998). The base period for construction of new series of index numbers of present study was taken as the average of three years 2005-06, 2006-07 and 2007-08.

RESULTS AND DISCUSSION

Paddy

Paddy is one of the most important among cereal crops in Gujarat state. Ahmadabad, Anand, Kheda, Surat, Panchmahamal, Navsari, Valsad, Vadodara, Dahod, Tapi, Dang, Bharuch, Sabarkantha, Narmada and Banaskantha are the main paddy growing districts of the state.

Compound growth rates (CGRs) and instability index (II) for inputs costs and output prices of paddy crop reflect the positive and significantly higher growth rate for output prices (7.69%) in comparison to total input cost (5.51%) (Table 1). Input wise the highest growth rate was found in manures followed by human labour and seed cost. This was due to the increasing prices of these inputs in market and is not in favour of farmers. The non-significant negative growth was also observed in irrigation and insecticide/ pesticides charges. The result of the instability index for output prices was found to be slightly higher (13.84) in comparison to total input costs (12.76). The instability index of various inputs varied from 8.68 to 23.17.

Table 1. Compound growth rate and Iinstability index of input cost and output prices of paddy in Gujarat state (2001-02 to 2010-11)

S.No.	Particular	Compound growth rate (CGR)	Instability index (II)
1.	Human labour	8.30**	14.36
2.	Bullock labour	0.92	14.53
3.	Seeds	7.44**	8.86
4.	Manures	9.40**	20.37
5.	Chemical fertilizers	2.55*	8.68
6.	Irrigation	-1.99	22.77
7.	Insecticide/pesticides	-1.41	23.17
8.	Total cost (Rs/qt)	5.51**	12.76
9.	FHP (Rs/qt)	7.69**	13.84

** Significant at 1% level; * Significant at 5% level

Table 2. Parity indices of prices received for output and paid for inputs of paddy crop (Base 2005-06 to 2007-08 = 100)

Year	Index of prices received for output	Index of prices paid for inputs	Parity indices
2001-02	85.21	98.80	86.25
2002-03	94.34	96.57	97.68
2003-04	84.27	87.16	96.68
2004-05	86.96	90.57	96.02
2005-06	93.73	97.34	96.30
2006-07	100.81	107.36	93.90
2007-08	105.46	95.30	110.66
2008-09	129.06	124.73	103.48
2009-10	178.71	154.65	115.55
2010-11	148.04	145.81	101.53

The parity indices of paddy crop were more than 100 in last four years continuously right from 2007-08 to 2010-11 (Table 2). Therefore, it can be concluded that the output prices of paddy in last four years were in favour of farmers. This clearly indicates that the prices received for output of paddy increased higher than prices paid for inputs and therefore, the production of paddy became relatively more profitable.

Bajra

Bajra is one of the most important *khraif* cereal crop in Gujarat state. Banaskantha, Kheda, Patan, Mehsana, Anand, Kutch, Bhavnagar, Surendranagar, Gandhinagar, Sabarkantha, Junagadh, Vadodara Rajkot *etc.* are the main bajra growing districts of the state.

The positive and significantly higher growth rate was found for output prices (10.55%) in comparison to total input cost (5.91%). Input wise the significant and positive higher growth rate was found in seed costs, human labour, chemical fertilizer and bullock labour, whereas in case of insecticide/pesticides and manures costs, it was found to be non-significant. For irrigation charges, CGR was found to be non significant and negative. The instability index for output prices (12.59) was found to be higher than that of total input cost (6.55). The instability index of different inputs varied from 6.25 to 86.78 (Table 3).

The parity indices of prices received for output to prices paid for inputs used in bajra crop were more than 100 in 2002-03, 2005-06, 2006-07, and continuously in last three years *i.e.* from 2008-09 to 2010-11. This clearly indicates the prices received for output of bajra increased faster than that of prices paid for inputs and terms of trade for bajra became relatively in favour of farmers (Table 4).

Table 3. compound growth rate and instability index of input cost and output prices of bajra in Gujarat state (2001-02 to 2010-11)

S.No.	Particular	Compound growth rate (CGR)	Instability index (II)
1.	Human labour	7.47**	9.59
2.	Bullock labour	2.47*	6.25
3.	Seeds	13.69**	10.03
4.	Manures	6.25	21.56
5.	Chemical fertilizers	3.78**	7.66
6.	Irrigation	-8.5	86.78
7.	Insecticide/pesticides	18.39	67.23
8.	Total cost (Rs/qt)	5.91**	6.55
9.	FHP (Rs/qt)	10.55**	12.59

* Significant at 5% level; ** Significant at 1% level

Table 4. Parity indices of prices received for output and paid for inputs of bajra (Base 2005-06 to 2007-08 = 100)

Year	Index of prices received for output	Index of prices paid for inputs	Parity indices
2001-02	54.91	68.90	79.69
2002-03	80.95	78.15	103.58
2003-04	68.97	76.52	90.13
2004-05	82.22	87.38	94.10
2005-06	91.74	90.27	101.62
2006-07	114.24	112.76	101.31
2007-08	94.03	96.97	96.97
2008-09	103.37	101.79	101.55
2009-10	143.35	108.77	131.80
2010-11	165.02	122.84	134.34

Cotton (Long Staple)

Cotton is one of the most important cash crop of Gujarat state. Surendranagar, Bhavnagar, Rajkot, Amreli, Ahmadabad, Jamnagar, Vadodara, Bharuch, Sabarkantha, Kutch, Patan, Mehsana, Junagadh, Narmada, Gandhinagar, Banaskantha *etc.* are the main cotton growing districts of the state.

The positive and significantly higher growth rate was found for output prices (5.71%) in comparison to total input cost (1.00%). Input wise the positive and significantly highest growth rate was found in manures followed by seed, human labour, irrigation and chemical fertilizer and it was non- significant for insecticide/pesticides charges. The negative and non significant growth rate was observed in bullock labour charges. The instability index for output prices (14.92) was found to be slightly higher in comparison to that of total input costs (12.75). The instability index for different inputs ranged from 7.10 to 26.30 (Table 5).

Out of ten years, the parity indices of prices received for output in comparison to prices paid for inputs used in cultivation of cotton crop were less than 100 during six years *i.e.* in 2001-02, 2002-03, 2004-05, and from 2006-07 to 2008-09. Whereas in year 2003-04, 2005, 06 and last two years *i.e.* 2009-10 and 2010-11, the index of terms of trade for cotton were more than 100 indicating favour of farmers (Table 6).

Wheat

Wheat is one of the most important *rabi* crop in Gujarat state. Ahmadabad, Rajkot, Junagadh, Sabarkantha, Kheda, Banaskantha, Mehsana, Anand, Jamnagar, Surendranagar, Amreli, Gandhinagar *etc.* are the main wheat growing districts of the state.

Table 5. Compound growth rate and instability index of input cost and output prices of cotton in Gujarat state (2001-02 to 2010-11)

S.No.	Particular	Compound growth rate (CGR)	Instability index (II)
1.	Human labour	9.15**	7.10
2.	Bullock labour	-0.37	8.08
3.	Seeds	9.33*	26.30
4.	Manures	10.58**	13.43
5.	Chemical fertilizers	7.93**	12.86
6.	Irrigation	8.81**	15.02
7.	Insecticide/pesticides	6.55	24.74
8.	Total cost (Rs/qt)	1.00	12.75
9.	FHP (Rs/qt)	5.71**	14.92

* Significant at 5% level; ** Significant at 1% level

Table 6. Parity Indices of prices received for output and paid for inputs of cotton crop (Base 2005-06 to 2007-08 = 100)

Year	Index of prices received for output	Index of prices paid for inputs	Parity indices
2001-02	79.51	131.25	60.58
2002-03	98.31	115.96	84.78
2003-04	117.48	102.95	114.11
2004-05	87.32	95.31	91.61
2005-06	98.14	93.56	104.89
2006-07	99.38	103.10	96.39
2007-08	102.48	103.34	99.17
2008-09	117.78	126.86	92.84
2009-10	125.40	117.92	106.35
2010-11	172.19	133.35	129.13

The positive and significant higher growth rate was found for output prices (7.01%) in comparison to total input cost (4.9%). Input wise the significant and highest positive growth rate was found in manures (30. 32%) followed by insecticide/ pesticides, human labour, seed and irrigation charges. Whereas, it was non-significant for bullock labor and chemical fertilizer charges. There of instability index for output prices (10.15) was found to be lower in comparison to total input costs (24.92). The instability index for different inputs varied from 4.93 to 73.82 (Table 7).

The perusal of Table 8 revealed that the parity indices of wheat crop was not in favour of farmers in almost all the years except in years 2007-08 and 2009-10.

Pigeon pea (Tur)

Pigeonpea is one of the most important pulse crop of Gujarat state. Vadodara, Bharuch, Panchmal, Sabarkantha, Narmada, Dahod, Tapi, Surat, Valsad, Navsari, Dang, Kheda, Banaskantha and Amdavad are the main pigeonpea growing districts of the state.

The results of compound growth rates (CGRs) and instability index (II) for inputs costs and output prices of pigeon pea crop revealed positive and significantly higher growth rate for output prices (11.16%) in comparison to total input cost (5.24%). Input wise the significant and higher growth rate was found in cost of seeds (12.02%) followed by human labour (9.087%) and manures (9.73%) and it was found non-significant

Table 7. Compound growth rate and instability index of input cost and output prices of wheat in Gujarat state (2001-02 to 2010-11)

S.No.	Particular	Compound growth rate (CGR)	Instability index (II)
1.	Human labour	5.96**	13.27
2.	Bullock labour	2.36	12.37
3.	Seeds	5.58**	8.06
4.	Manures	30.32*	73.82
5.	Chemical fertilizers	0.41	4.93
6.	Irrigation	4.24*	13.32
7.	Insecticide/pesticides	11.77**	21.67
8.	Total cost (Rs/qt)	4.9	24.92
9.	FHP (Rs/qt)	7.01**	10.15

* Significant at 5% level; ** Significant at 1% level

Table 8. Parity indices of prices received for output and paid for inputs of wheat crop (Base 2005-06 to 2007-08 = 100)

Year	Index of prices received for output	Index of prices paid for inputs	Parity indices
2000-01	77.98	88.20	88.41
2001-02	75.73	89.82	84.32
2002-03	81.83	93.17	87.83
2003-04	75.16	83.82	89.67
2004-05	87.05	185.44	46.94
2005-06	82.85	84.28	98.30
2006-07	99.51	105.19	94.60
2007-08	117.65	110.53	106.44
2008-09	116.10	132.01	87.94
2009-10	144.89	144.61	100.19

for bullock labour, irrigation and insecticide/ pesticide charges. The result of the instability index for output prices (12.65) was found to be lower in comparison to that of total input costs (16.52). The instability index across various inputs varied from 12.64 to 79.68 (Table 9). The high growth and low instability are prerequisites for sustainable agricultural performance. Hence, the magnitude of growth and instability in pigeon pea crop has serious implications for policy makers.

The parity indices of prices received for output in comparison to price paid for inputs of tur crop was more than 100 continuously for last four years *i.e.* right from 2007-08 to 2010-11 (Table 10). This clearly indicates that the prices received for output of pigeon pea increased much higher than prices paid for inputs in last four years and the production of tur became relatively profitable now.

The above findings were supported by Kahlon (1998) reported improvement in terms of trade in favour of agriculture is only a recent phenomenon which needs to be sustained.

CONCLUSION

It can be concluded from the aforesaid findings that the compound growth rate was found higher in case of output prices in comparison to total input cost. The high growth rate and low instability for output prices was the good sign for farmers in all five major crops. The improvement in terms of trade was in favour of farmers in case of paddy, pigeon pea, bajra and cotton crops, which needs to be sustained, where as in case of wheat the parity indices was not much in favour of farmers in last ten years. This clearly indicates that the prices received for output did not increase in proportion to the prices paid for inputs.

Table 9. Compound growth rate and instability index of input cost and output prices of tur in Gujarat state (2001-02 to 2010-11)

S.No.	Particular	Compound growth rate (CGR)	Instability index (II)
1.	Human labour	9.87**	12.64
2.	Bullock labour	3.4	18.25
3.	Seeds	12.02**	18.31
4.	Manures	9.73**	25.01
5.	Chemical fertilizers	-1.43	50.84
6.	Irrigation	14.52	79.68
7.	Insecticide/pesticides	5.79	58.65
8.	Total cost (Rs/qt)	5.24*	16.52
9.	FHP (Rs/qt)	11.16**	12.65

* Significant at 5% level; ** Significant at 1% level

Table 10. Parity indices of prices received for output and paid for inputs of tur crop (Base 2005-06 to 2007-08 = 100)

Year	Index of prices received for output	Index of prices paid for inputs	Parity indices
2001-02	76.74	113.70	67.49
2002-03	79.13	102.86	76.92
2003-04	78.42	93.14	84.19
2004-05	84.41	91.71	92.04
2005-06	87.56	82.38	106.29
2006-07	99.47	114.08	87.19
2007-08	112.97	103.54	109.11
2008-09	141.83	134.42	105.51
2009-10	188.68	152.23	123.94
2010-11	174.87	161.64	108.19

Policy Implications

The findings of the present study would be of practical significance for the researchers, extension personnel, policy makers, planners, administrators and farmers :

- During last decade positive and higher growth rate for output prices in comparison to total input cost was observed in most of the crops. This indicates that the farming became more profitable and farmers' income increased. This is good sign for sustainable agricultural performance.
- The parity indices reveals that the improvement in terms of trade was in favour of farmers in case of paddy, pigeon pea, bajra and cotton crops which needs to be sustained whereas in case of wheat, the parity indices was not much in favour of farmers in last ten years. This indicates that the prices received for output was not increased in proportion to the prices paid for inputs in these crops. Therefore, appropriate policy should be formulated considering these findings.

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Assessment of different methods of sowing of vegetable cowpea to harness productivity and profitability potential

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ABSTRACT

Cowpea is one of the important leguminous vegetables, an important source of nutrients and high quality protein to cereal based diets. The variety 'Kashi Kanchan' with high production potential developed from Indian Institute of Vegetable Research, Varanasi is preferred by farmers. Three methods of sowing with recommended package practices were assessed in order to achieve the productivity potential. Highest number of pods plant^{-1} (27.6 and 27.6), plant height (58.3 and 59.5 cm) and yield (135.5 and 125.4 q ha^{-1}) was recorded in raised bed method of sowing during 2012 and 2013, respectively. Similarly, highest net return ₹98300 ha^{-1} and ₹95740 ha^{-1} with highest B:C ratio 3.64 and 3.27 was also observed in raised bed method of sowing during 2012 and 2013, respectively.

Key words: Cowpea, growth, economics, sowing methods, yield.

Cowpea, *Vigna unguiculata* (L.) Walp, is an important leguminous crop and commercially grown throughout India for its green pods as vegetable, seeds as pulse and foliage as fodder. Rural families can get food protein (Bressani, 1985), animal feed (Tarawali *et al.*, 1997; Singh, 1999) and cash from the production of this crop (Quin, 1997). In terms of nutrition, it is having good quality nutrients as high and quality inexpensive protein as compared to diets based on cereals grains. Mature seed of cowpea contains 24.8% protein, 63.6% carbohydrate, 6.3% fibre, 1.9% fat, 0.00074% thiamine, 0.00042% riboflavin and 0.00281% niacin (Davis *et al.*, 2000). Besides, the crop also fixes 80% nitrogen for its growth demand from the atmosphere (Asiwe, 2009), thereby reducing nitrogen fertilizer demand and cost of production. It is also an important companion crop in most cereal-legume cropping systems because of the benefit from the residual nitrogen originating from the decay of its leaf litter, roots and root nodules (Mohammed and Mohammed, 2014). There are mainly two types of cowpeas - for grain and vegetable purposes. Generally grain type cowpea varieties produce short pods with more number of seeds and mature early whereas, vegetable type varieties produce long pods with less number of seeds and mature late and the pods remain tender and soft for longer period. Cowpea varieties with long pods and indeterminate in growth habit are generally cultivated as vegetable type. However, with the development of new varieties, vegetable type cowpeas both determinate and indeterminate in growth habit are prevalent. But, farmers prefer determinate type due to its earliness and low cost of cultivation. Cowpea is generally grown on marginal lands with little or no inputs and therefore the yield is very low.

The production practices of cowpea followed by most of the farmers are not based on the scientific background and even a promising cultivar does not perform well. Similarly, the crop production particularly in problematic soil (primarily salt affected soils) is not up to the mark. Therefore, the productivity of cowpea has yet to be reached at a desired level. In order to increase the area under cowpea, it was necessary to conduct the on farm trials with suitable method of sowing along with a promising cultivar to improve the quality production of cowpea.

Materials and Methods

The experiments were conducted by Krishi Vigyan Kendra, Bhadohi during Zaid seasons of 2012 and 2013. The land is situated in between 25.12° & 25.32° north latitude and 82.12° & 82.42° east longitude. The temperature ranges between 5° to 46°C and annual rainfall of 1563 mm. The experiment was conducted in Randomized Complete Block Design (RCBD) with three treatments as method of sowing namely T1: Flat method, T2: Ridge method (top of ridge was 60 cm apart) and T3: Raised bed method (bed width was 90 cm and 30 cm width of drainage channel) and five replications. Individual plot size of the experiment was 250 m^2.

A promising cultivar 'Kashi Kanchan' evolved from Indian Institute of Vegetable Research; Varanasi was selected for the study. This variety is resistant to *Golden Yellow Mosaic* disease. Farm yard manure was applied @ 20 t ha^{-1} prior to sowing. The crop was sown in the second fortnight of February during both the years. The seeds were placed 10 cm apart and 60 cm spacing was maintained in row to row. Irrigation was scheduled in an interval of 8-10 days as per requirement. N:P:K was applied @ 25:60:60 kg ha^{-1}. Full dose of phosphorus and potash and half dose of nitrogen were applied as basal at the time of field preparation and remaining half dose of nitrogen was applied after 30 days of sowing. The pods were picked as and when matured. Five spots were randomly selected to assess the no. of pods $plant^{-1}$, length of pods (cm), height of plant (cm). Total yield (q ha^{-1}) was calculated from individual plot and analyzed. The economic parameters were also studied in terms of total cost of production (₹ ha^{-1}), gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and benefit cost ratio.

Results and Discussion

It is evident from Table 1 that the highest number of pods $plant^{-1}$ (27.6) was observed in raised bed method of sowing followed by ridge method of sowing (26.2) and flat method (23.6) during 2012. Number of pods $plant^{-1}$ observed in raised bed method was statistically significant with flat method. However, number of pods $plant^{-1}$ was not statistically differed with flat method and ridge method and similar is the case with ridge method and raised bed method. Highest length of pods (27.1 cm) was observed in ridge method followed by raised bed method (25.8 cm) and flat method (22.7 cm) during 2012. The length of pods in ridge method was statistically different from flat method and raised bed method and statistically at par in ridge method and raised bed method. It is one of the major criteria to select better variety for its higher yield and preferable pod size. Longer pods are the preferred and higher marketability character of cowpea. It is also obvious that the longer pods produce more yield than shorter pods. In this way, the pods produced in ridge method and raised bed method proved to be of superior quality.

Highest plant height was also observed in raised bed (58.3 cm) followed by ridge method

Table 1. Growth and yield parameters of cowpea production during 2012

Parameters	No. of pods/plant	Length of pods (cm)	Plant height (cm)	Yield (q/ha)
Flat method	23.6^b	22.7^b	48.2^b	112.6^b
Ridge method	26.2^b	27.1^a	52.7^b	126.9^a
Raised bed method	27.6^a	25.8^a	58.3^a	135.5^a
SEm ±	1.25	1.08	2.14	4.56
CD (P=0.05)	2.89	2.49	4.94	10.52

(52.7 cm) and flat method (48.2 cm) during 2012. Plant height in flat method and ridge method was statistically at par and differed in flat method and raised bed method and in between ridge method and raised bed method. Similarly, the highest yield was observed in raised bed (135.5 q ha^{-1}) followed by ridge method (126.9 q ha^{-1}) and flat method (112.6 q ha^{-1}) during 2012. Yield in flat method was statistically different from ridge method and raised bed method, however, yield in ridge method and raised bed method were statistically at par. The results indicate that the uptake of nutrients, space etc. might be utilized efficiently in raised bed method of sowing followed by ridge method of sowing. Besides, poor weed competition might be one of the reasons for higher yield in raised bed.

Table 2 also depicts that the highest number of pods plant^{-1} (27.6) was observed in raised bed method of sowing followed by ridge method of sowing (26.0) and flat method (24.4) during 2013. Number of pods plant^{-1} observed in raised bed method was statistically significant with flat method. However, number of pods plant^{-1} was not statistically differed with flat method and ridge method; ridge method and raised bed method. Highest length of pods (24.7 cm) was observed in ridge method followed by raised bed method (24.0 cm) and flat method (19.6 cm) during 2013. The length of pods in ridge method was statistically different from flat method and ridge method; flat and raised bed method and statistically at par in ridge method and raised bed method. Highest plant height was also observed in raised bed (59.5 cm) followed by ridge method (53.2 cm) and flat method (51.0 cm) during 2013. Plant height in flat method and ridge method was statistically at par and differed in flat method and raised bed method and in between ridge method and raised bed method. Similarly, the highest yield was observed in raised bed (125.4 q ha^{-1}) followed by ridge method (115.7 q ha^{-1}) and flat method (105.2 q ha^{-1}) during 2013. Yield in flat method was statistically different from ridge method and raised bed method and flat method. The results indicate that the higher yield in raised bed might be due to highest water use efficiency in addition to above mentioned speculations. The roots absorb water and nutrients from either sides or aeration takes place from other sides. Besides, salt accumulation may not take place in ridge method and raised bed method of sowing in comparison to flat method.

As far as economic parameters are concerned, highest gross cost incurred in ridge method (₹ 38600 ha^{-1}) followed by raised bed (₹ 37200 ha^{-1}) and flat method (₹ 35450 ha^{-1}) during 2012 (Table 3). However, gross return hectare^{-1} was highest in raised bed method (₹ 135500) followed by ridge method (₹ 126900) and flat method

Table 2. Growth and yield parameters of cowpea production during 2013

Parameters	No. of pods/plant	Length of pods (cm)	Plant height (cm)	Yield (q/ha)
Flat method	24.4^{b}	19.6^{b}	51.0^{b}	105.2^{c}
Ridge method	26.0^{ab}	24.7^{a}	53.2^{b}	115.7^{b}
Raised bed method	27.6^{a}	24.0^{a}	59.5^{a}	125.4^{a}
SEm ±	0.72	0.99	2.39	3.92
CD (P=0.05)	1.66	2.29	5.50	9.03

Table 3. Economic parameters of production of cowpea.

Parameters	Gross cost (₹/ha)		Gross return (₹/ha)		Net return (₹/ha)		B:C ratio	
	2012	2013	2012	2013	2012	2013	2012	2013
Flat method	35450	40600	112600	115720	77150	75120	3.17	2.85
Ridge method	38600	43300	126900	127270	88300	83970	3.28	2.94
Raised bed method	37200	42200	135500	137940	98300	95740	3.64	3.27

(₹ 112600) and highest net return ₹ 98300 ha^{-1} was observed in raised bed method followed by ridge method (₹88300 ha^{-1}) and flat bed (₹77150 ha^{-1}). The highest return in raised bed method might be due to highest yield and least gross cost of cultivation in comparison to ridge method of sowing. Similarly, highest benefit cost ratio (3.64) was observed in raised bed followed by ridge method (3.28) and flat method (3.17).

Table 3 also exhibits the highest gross cost incurred in ridge method (₹ 43300 ha^{-1}) followed by raised bed (₹ 42200 ha^{-1}) and flat method (₹ 40600 ha^{-1}) during 2013. However, gross return $hectare^{-1}$ was highest in raised bed method (₹ 137940) followed by ridge method (₹ 127270) and flat method (₹ 115720) and highest net return ₹ 95740 ha^{-1} was observed in raised bed method followed by ridge method (₹ 83970 ha^{-1}) and flat method (₹ 75120 ha^{-1}). Similarly, highest benefit cost ratio (3.27) was observed in raised bed followed by ridge method (2.94) and flat method (2.85). The highest return in raised bed method might be due to highest yield and less gross cost of cultivation in comparison to ridge method. Though, the cost of cultivation was less in flat method but yield was not higher in comparison to other two methods. Singh *et al.* (2007 and 2012) also advocated the cultivation practices of improved variety 'Kashi Kanchan'.

On the basis of yield performance and market returns, raised bed method of sowing may be recommended in cultivation of cowpea. The next alternative could be ridge method of sowing. Though, the cost was higher in ridge method but higher yield and good market may replace the prevalent flat method of sowing.

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Adoption of spice crops technological interventions in arid Rajasthan

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ABSTRACT

This study was conducted in Jodhpur (Rajasthan) in the year 2010 to know the extent of adoption of respondents regarding different technological interventions of spice crops. A sample of 160 respondents was taken from IVLP operated (Beneficiary) and non-operated (Non-beneficiary) villages. Further, the extent of adoption of package of practices of spice crops was measured by a questionnaire and then MPS was calculated, ranks were assigned and Correlation in ranks was also determined. The findings revealed that more number of beneficiary respondents fall in high adoption group as compared to non-beneficiary. There was significant correlation between the ranks given to adoption of various package of practices of spice crops production technology by the beneficiaries and non-beneficiar respondents. There was significant difference in the extent of adoption also between both the respondents.

Key words: Adoption, beneficiary, Institutional Village Linkage Programme (IVLP), correlation, spice crops.

In the modern era many new things are being investigated by our agricultural scientists but all the innovations are not being adopted by many of the members of a social system. Adoption is a mental process. Adoption of an innovation depends on many factors *viz.*, awareness and knowledge of adopters, innovativeness, complexity and visibility of an innovation (Choudhary *et al.* 2013). Rajasthan contributes 17% to the total spices production. This study is confined mainly to three spice crops namely, cumin, Chili and Onion. The area of Cumin in 2013-14 in Rajasthan was 4.88 Lakh ha and production was 2.33 Lakh tones. Similarly, Chilli was cultivated in 0.67 Lakh ha area and production was 1.10 Lakh tones and Onion was cultivated in 0.57 Lakh ha area and production was 7.04 Lakh tones (Anonymous, 2014). Still, there is a great scope for increasing the production and productivity of these spices in Rajasthan through increasing the rate of adoption of spice production technologies by introducing the Institutional Village Linkage Programme (IVLP). This programme lays emphasis on problem diagnosis, technology intervention and assessment through user's participatory research mode. So to increase the adoption of the interventions which in turn would lead to enhanced production of these spices in the study area the present study was undertaken with the following specific objective:

(1) To determine the extent of adoption of IVLP beneficiary and non-beneficiary respondents regarding different technological interventions related to selected spices cultivation.

MATERIALS AND METHODS

In Rajasthan, the project on Technology Assessment and Refinement (TAR) through IVLP was started in the year 2000 in Jodhpur to cater the location specific needs of farmers in rainfed and arid ecosystem. The present study was conducted in Jodhpur district. There was only one centre of IVLP for arid-ecosystem in Rajasthan which was located at CAZRI, Jodhpur. Out of nine panchayat samities, only one panchayat samiti i.e. Mandore was selected purposively because the programme of IVLP was operated in this panchayat samiti only. Out of five villages in the panchayat samiti, three villages were purposively selected because more number of beneficiary respondents were from these villages only. Another three villages where the IVLP project was not operated were selected randomly within the radius of 10-15 km from the IVLP selected villages. In all a sample of 160 farmers was taken i.e. 80 from IVLP operated villages called beneficiary respondents and 80 from IVLP non-operated villages called non-beneficiary respondents.

RESULTS AND DISCUSSION

Overall of Spice crops : Table-1 shows that half of spice growing beneficiary as well as non-beneficiary respondents have medium extent of adoption. Further, 33.75% and 16.25% beneficiary respondents belonged to low and high extent of adoption category, respectively. In case of non-beneficiary of spice crops growers 42.5% and 07.50% had low and high extent of adoption category, respectively. These findings are in conformity with the findings obtained by Yadav et al. (2011-2013).

(A) *Extent of adoption of respondents regarding cumin, chilli, onion and spice crops production technology*

The practice wise extent of adoption for cumin, chilli, onion and spice crops were worked out for beneficiary and non-beneficiary respondents. The data pertaining to these have been presented in Table-2.

Cumin crop : In case of beneficiary respondents, the practices like 'high yielding varieties' and 'seed rate and spacing' were adopted with 76.9 and 71.5 MPS and ranked at 1st and 2nd, respectively Further, they had more than 60.0 MPS adoption level in the practices like 'seed treatment', 'weed management', 'field preparation' and 'irrigation management'. The least adopted practices by them were 'plant protection measures' and 'time of sowing' with 57.3 and 56.4 MPS, respectively. In case of non-beneficiary respondents, they adopted the practices like 'seed treatment', 'seed rate & spacing' and 'field preparation' with more than 50.0 MPS. They adopted practices like 'plant protection measures' and 'irrigation management' to the lesser extent.

Chilli crop : In case of beneficiary respondents of chilli, they possessed comparatively more adoption regarding 'high yielding varieties' and 'harvesting, threshing & storage' were adopted with 76.9 and 73.1 MPS and ranked at 1st and 2nd, respectively. They had medium adoption level in the practices like 'weed management' (65.4 MPS) and 'field preparation' (61.5 MPS) were ranked at 5th and 6th, places respectively. The least adopted practices by them were 'time of sowing' and 'irrigation management' with 56.4 and 53.9 MPS, respectively. In case of non-beneficiary respondents, the practices like 'seed rate & spacing' and 'harvesting, threshing & storage' were adopted with 48.1 and 46.2 MPS and ranked at 1st and 2nd places, respectively. They possessed medium adoption level in the practices like 'high yielding varieties' (41.0 MPS) and 'plant protection measures' (40.0 MPS) and assigned rank 5th and 6th, respectively. The practices which were least adopted by them were 'weed management' and 'irrigation management' with 23.1 and 15.4 MPS, respectively.

Onion crop : The beneficiary respondents of onion crop adopted the practices like 'high yielding varieties' and 'weed management' to greater extent. Further, they had more than 60.0 MPS adoption level in the practices like 'harvesting, threshing & storage', 'seed rate & spacing', 'seed treatment' and 'fertilizer application'. The least adopted practices by them were 'field preparation' and 'plant protection measures'. The non-beneficiary respondents of onion crops had poor adoption level compared to beneficiary respondents. They adopted only one practice *i.e.* 'high yielding varieties' upto 40.0 MPS. Their adoption level in the remaining

Table 1. Distribution of respondents on the basis of adoption level of spice crops.

Sl. No	Categories (Means Score)	Cumin crop				Chilli crop				Onion crop				Overall of spice crops			
		Beneficiary (N=52)		Non-beneficiary (N=52)		Beneficiary (N=13)		Non-beneficiary (N=13)		Beneficiary (N=15)		Non-beneficiary (N=15)		Beneficiary (N=80)		Non-beneficiary (N=80)	
		F	%	F	%	F	%	F	%	F	%	F	%	F	%	F	%
1.	Low (<24.07)	18	34.6	23	44.2	5	38.5	5	38.5	4	26.7	6	40.0	27	33.7	34	42.5
2.	Medium (24.07-52.60)	26	50.0	25	48.1	6	46.2	7	53.8	8	53.3	8	53.3	40	50.0	40	50.0
3.	High (>52.60)	8	15.4	4	7.7	2	15.4	1	7.7	3	20.0	1	6.7	13	16.3	6	7.5
	Pooled	52	100.0	52	100.0	13	100.0	13	100.0	15	100.0	15	100.0	80	100.0	80	100.0

F = Frequency; % = Percentage

Table 2. Extent of adoption of respondents regarding cumin, chilli, onion and spice crops production technology.

Sl. No	Practices	Cumin crop				Chilli crop				Onion crop				Overall of spice crops			
		Beneficiary (N=52)		Non-beneficiary (N=52)		Beneficiary (N=13)		Non-beneficiary (N=13)		Beneficiary (N=15)		Non-beneficiary (N=15)		Beneficiary (N=80)		Non-beneficiary (N=80)	
		MPS	Rank	MPS	Rank	MPS	Rank	MPS	Rank	MPS	Rank	MPS	Rank	MPS	Rank	MPS	Rank
1.	Field preparation	65.4	5	51.0	3	61.5	6	42.3	4	52.6	9	33.3	7	59.8	6	42.2	4
2.	High yielding varieties	76.9	1	46.2	5	76.9	1	41.0	5	73.3	1	40.0	1	75.7	1	42.4	3
3.	Seed treatment	68.0	3	53.8	1	71.8	3	45.3	3	63.7	5	39.3	2	67.8	2	46.1	1
4.	Time of sowing	56.4	10	42.9	8	56.4	9	38.5	7	55.6	7	28.9	9	56.1	10	36.8	8
5.	Seed rate & spacing	71.5	2	53.2	2	67.3	4	48.1	1	63.9	4	36.1	4	67.6	3	45.8	2
6.	Fertilizer application	59.2	7	44.9	7	59.8	8	30.8	8	60.0	6	35.6	6	57.2	7	37.1	7
7.	Irrigation management	61.5	6	32.7	10	53.9	10	15.4	10	53.3	8	20.0	10	56.2	9	22.7	10
8.	Weed management	66.4	4	45.2	6	65.4	5	23.1	9	70.0	2	36.7	3	67.2	4	35.0	9
9.	Plant protection measures	57.3	9	38.8	9	60.0	7	40.0	6	52.0	10	36.0	5	56.4	8	38.3	6
10.	Harvesting, threshing & storage	58.7	8	48.1	4	73.1	2	46.2	2	66.7	3	30.0	8	66.1	5	41.4	5
	Pooled	64.1		45.7		64.6		37.1		61.1		33.6		63.0		38.8	
				r_s = 0.61* T = 2.74				r_s =0.70* t=2.78				r_s =0.56* t=1.93				r_s =0.73* t=3.05	

r_s = Rank correlation; *Significant at 5% level of significance, MPS = Mean Percent Score practices except 'time of sowing' and 'irrigation management' was between 30.0 to 40.0 MPS.

Overall of Spice crops : In case of spice crops beneficiary respondents, the practices like 'high yielding varieties', 'seed treatment' and 'seed rate & spacing' were adopted with 75.7, 67.8 and 67.6 MPS, respectively. Similarly they had medium adoption level in the practices like 'weed management' (67.2 MPS), 'harvesting, threshing & storage' (66.1 MPS) and 'field preparation (63.4 MPS) were ranked at 4th, 5th and 6th, places respectively. The least adopted practices by them were 'plant protection measures', 'irrigation management' and 'time of sowing' with 56.4, 56.2 and 56.1 MPS, respectively. In case of spice crops non-beneficiary respondents, the practices like 'seed treatment', 'seed rate & spacing' and 'field preparation' were adopted with 46.1, 45.8 and 42.2 MPS and ranked at 1st, 2nd and 3rd, respectively. They possessed medium adoption level in the practices like 'harvesting, threshing & storage' (41.4 MPS), 'fertilizer application' (40.5 MPS) and 'high yielding varieties (39.0 MPS) and assigned rank 4th, 5th and 6th, respectively. The practices which were least adopted by them were 'time of sowing', 'weed management' and 'irrigation management' with 36.8, 35.0 and 22.7 MPS, respectively. The overall extent of adoption regarding cumin, chilli, onion and overall spice crops production techno-logy by the beneficiary respondents were 64.1, 64.6, 61.4 and 63.4 MPS, respectively, whereas, the extent of adoption of non-beneficiary respondents for the above crops were 45.7, 37.1, 33.6 and 38.8 MPS, respectively. To see the relationship between the ranks assigned by beneficiary and non-beneficiary respondents the Rank Order Correlation was worked out. The values of calculated Rank Order Correlation (r_s) were 0.6, 0.7, 0.6 and 0.7 for cumin, chilli, onion and overall of spice crops, respectively. The significance of r_s was tested by 't' test and it was observed that calculated 't' value was higher than it's table value in all the cases. This leads to conclusion that there is correlation in ranking in the extent of adoption between beneficiary and non-beneficiary respondents regarding cumin, chilli, onion and overall spice crops production technology, though there was difference in magnitude of MPS beneficiary and

Table 3. Comparison of extent of adoption regarding spice crops production technology by the respondents.

Sl. No	Categories (Mean Score)	Cumin crop (Mean)			Chilli crop (Mean)			Onion crop (Mean)			Overall of spice crops (Mean)		
		Beneficiary (N=52)	Non-beneficiary (N=52)	'Z' value	Beneficiary (N=52)	Non-beneficiary (N=52)	'Z' value	Beneficiary (N=52)	Non-beneficiary (N=52)	'Z' value	Beneficiary (N=52)	Non-beneficiary (N=52)	'Z' value
1.	Field preparation	3.9	3.1	2.31*	3.7	2.5	2.05NS	3.8	2.4	2.08*	3.8	2.7	4.21**
2.	High yielding varieties	2.3	1.4	3.40**	2.3	0.9	2.66**	2.2	1.0	2.40*	2.3	1.1	5.41**
3.	Seed treatment	6.1	4.9	2.37*	6.5	4.1	3.17**	5.7	4.4	4.21**	6.1	4.4	6.56**
4.	Time of sowing	1.7	1.3	2.55*	1.7	1.2	2.45*	1.7	0.9	2.15*	1.7	1.1	4.66**
5.	Seed rate & spacing	8.6	6.4	4.41**	8.1	5.8	3.23**	7.7	5.9	5.28**	8.1	6.0	7.39**
6.	Fertilizer application	5.3	4.0	4.04**	5.4	3.7	2.34*	4.7	3.8	2.68**	5.1	3.8	5.90**
7.	Irrigation management	1.8	1.0	3.08**	1.6	0.5	2.25*	1.6	0.6	2.02*	1.7	0.7	4.63**
8.	Weed management	4.0	2.7	2.63**	3.9	1.4	2.76**	4.2	2.6	2.38*	4.0	2.2	5.33**
9.	Plant protection measures	8.6	5.8	5.09**	9.0	6.0	3.26**	7.8	5.8	3.42**	8.5	5.9	7.17**
10.	Harvesting, threshing & storage	3.5	2.9	3.59**	4.4	2.77	2.20*	4.0	2.2	2.38*	3.7	2.6	4.42**
	Pooled	4.6	3.3	3.35**	4.7	2.9	2.64*	4.3	3.0	2.90**	4.5	3.1	5.57**

* Significant at 5% level of significance; ** Significant at 1% level of significance

non-beneficiary respondents.

(B) *Extent of adoption of respondents regarding spice crops production technology*

It is clear from the data of Table-3 that practice wise as well as overall calculated 'z' value between beneficiary and non-beneficiary was greater than its table value at 5 and 1% level of significance in all the 10 practices of spice crops production technology. This leads to the conclusion that there existed practice wise significant difference in level of adoption between beneficiary and non-beneficiary respondents regarding all the practices of spice crops production technology. The significant difference between beneficiary and non-beneficiary respondents about adoption of Technology Assessment and Refinement (TAR) programme in the study area was not unexpected. It might have been due to the fact that beneficiary respondents being in continuous touch with the IVLP personnel and might have acquired sufficient technical know-how pertaining to TAR programme (Chaudhary and Suri, 2014a, 2014b) Thus, they are more likely to practice the latest technical know-how (Yadav *et al.* 2012). These findings are also supported by Kumawat (2005), Patel (2005), Jaitawat (2006) and Choudhary (2008) who found that beneficiary farmers had higher knowledge than the non-beneficiary farmers regarding cumin, chilli and onion cultivation technologies.

CONCLUSION

From the findings it can be concluded that majority of spice crops beneficiary and non-beneficiary respondents were in medium adoption group followed by low and high, respectively. More number of beneficiary respondents fall in high adoption group as compared to non-beneficiary respondents. The spice crops beneficiary respondents possessed comparatively more adoption level regarding 'high yielding varieties', 'seed treatment' and 'seed rate & spacing'. Minimum adoption level possessed by them was in 'irrigation management' and 'time of sowing', whereas, spice crops non-beneficiary respondents had more adoption level regarding 'seed treatment', 'seed rate & spacing' and 'high yielding varieties'. They also possessed least knowledge regarding 'irrigation management'. There was significant correlation between ranks given to adoption of various package of practices of cumin, chilli, onion and overall spice crops cultivation by the beneficiary and non-beneficiary respondents. There was significant difference in the extent of adoption of cumin, chilli, onion and overall spice crops production technology between beneficiary and non-beneficiary respondents.

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An economics of paddy during pre-and post-National Food Security Mission in Bhandara District of Maharashtra

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ABSTRACT

National Food Security Mission (NFSM) was implemented with an objective to increase the productivity of major cereals and pulses including paddy by providing inputs like seeds, fertilizers, implements, irrigation facility, etc. It resulted in shift in cropping pattern and realization of higher net return. This study was conducted in Bhandara District of Maharashtra to assess the impact of NFSM on net return of paddy crop. A total of 50 samples including 35 small and 15 medium farmers were selected from the highest paddy producing block viz. Bhandara block out of seven blocks of the Bhandara District. The period of study for pre NFSM and post NFSM was 2006-07 and 2010-11, respectively. The total investment was highest on small farms followed by medium farms in both pre NFSM and post NFSM period. It was Rs.66834 and Rs.61835 per hectare on small and medium farms which was found to be higher as compared to pre NFSM investment of Rs.28255 and Rs.27097 per hectare in small and medium farms respectively. The price of paddy in post NFSM was found to be relatively higher than that of pre NFSM price in the study area. Net income and output-input ratio was higher in post NFSM. Thus, average incremental net income was Rs.9065 per hectare realizing that paddy cultivation after NFSM was economically viable and profitable over pre NFSM in the study area. Benefit cost ratio of paddy production in post NFSM was found to be higher than that of the pre NFSM. The increased B:C ratio clearly indicated the positive impact of NFSM on paddy production. Irrigation facility served as a catalyst in paddy production.

Key words: Benefit cost ratio, investment, cost, NFSM.

Paddy is the staple food for about 50 per cent of the population in Asia, where 90 per cent of the world's rice is grown and consumed. Asia's food security depends largely on the irrigated rice fields, which account for more than 75 per cent of the total rice production (Virk *et al.*, 2004). India requires to increase rice production by 3 million tonnes every year to ensure food security (Dass *et. al.*, 2015). Rice is the second important crop after Jowar in Maharashtra state. This is grown over an area of 14.99 lakh hectares with an annual production of 32.37 lakh tones. The average productivity of the state is 2.01 t ha^{-1}. Maharashtra ranks 13th in paddy production in the country. The total area under rice crop remained stable around 15 lakh ha and production around 24 lakh tones with 1.7 to 1.9 t ha^{-1} productivity during last 15 years in the state (Thaware *et al.*, 2010). The sustained growth of any processing industry depends on the viability which is largely determined by the cost of production and management efficiency in processing. Cost of production is an important variable that influences the profits, which are also an indicator of management efficiency (Shwetha *et al.*, 2011). Therefore, the present study is an attempt to find cost and return, cost concept, profitability and productivity of paddy by implementation of the

National Food Security Mission (NFSM). Cost and returns received from cultivation of rice by non beneficiaries and beneficiaries of NFSM was taken into consideration for assessing the change in production by National Food Security Mission. The investigations also envisaged the constraints of production and productivity related to rice crop.

MATERIALS AND METHODS

The study was conducted in Bhandara District of Maharashtra. Bhandara district under East vidarbha region of Maharashtra was selected purposively for National Food Security Mission on rice production. Paddy is the main crop in Bhandara district and occupied the maximum area under *kharif* season (*i.e.* 70.12%). The Bhandara district comprises of seven blocks out of which, Bhandara block was selected purposively (having highest production) for rice crop. In Bhandara block there are 142 villages (2010-11), a list of paddy producing villages was prepared and two villages were selected purposively. In both villages paddy growers were categorized under small and medium farmers and the list of paddy growers was prepared. In the selected villages it was observed that most of the farmers were having very small land holdings. The farmers were categorized into two size groups as small farmers (up to 2 ha) and medium farmers (above 2.01 ha) only for the purpose of this study. Therefore, 35 farmers from small farmers category and 15 farmers from medium farmers category were selected for the study. For the collection of required primary data survey method was adopted to conduct the enquiry by personal visits and interview schedule used to collect the relevant information from the respondents for the study *i.e.* cost of production of paddy (Pre NFSM and Post NFSM). The relevant information pertains to the agriculture year 2010-11 for the primary data and the period of study for Pre NFSM and Post NFSM was 2006-07 and 2010-11, respectively.

The cost concepts approach to farm costing is widely used in India (Raju V.T and Rao D.V.S., 1990). These cost concepts include Cost A_1, Cost A_2, Cost B_1, Cost B_2, Cost C_1, Cost C_2 and Cost C_3. Various costs have been worked out by applying following concepts :

Cost A_1 = All actual expenses in cash and kind incurred in production

Cost A_2 = Cost A_1 + Rent paid for leased in land

Cost B_1 = Cost A_1 + Interest on value of owned capital assets

Cost B_2 = Cost B_1 + Rental value of owned land and rent paid for leased in land

Cost C_1 = Cost B_1 + Imputed value of family labour

Cost C_2 = Cost B_2 + Imputed value of family labour

Cost C_3 = Cost C_2 + 10% of Cost C_2

RESULTS AND DISCUSSION

The analysis revealed that paddy has been highly labour intensive crop during pre NFSM period, the labour cost accounted for 53.09 per cent of the total cost which varied from 53.13 per cent in small farm to 53.04 per cent in large farm (Table 1). Among material cost, fertilizer contributed to about one-third of the total cost which was lowest (Rs. 978/ha) in medium farm and highest being in large farm (Rs. 1026/ha). Seed, manure and plant protection together contribute 8.36 to 8.43 per cent of the total cost for different size groups. In the first decade of 21st century there was decline in the production of paddy. To increase the production the HYV of paddy are introduced and for that there was a need of more fertilizer, more irrigation. On introduction of the mission there was an increase in the cost of irrigation than in earlier period (Birthal *et. al.* 2010). Therefore, the irrigation cost was zero during pre NFSM period because of lack of irrigation facilities before the national food security mission. There was completely rain fed cultivation of paddy. Interest on working capital was to the extent of 6.51 per cent of total cost on various sizes of farms. Average rental value of land fixed items was shared nearly about 11.66 per cent of the total cost revealed increasing trend with farm size in absolute terms.

Post NFSM period, there was reduction in the proportion of the labour cost which accounted to 50.15 per cent of the total cost which varied from 50.48 per cent in small farm to 49.79 per cent

Table 1. Cost of cultivation of paddy crop

		(Rs/ha)					
S. No.	Particulars	Pre NFSM			Post NFSM*		
		Small	Medium	Overall	Small	Medium	Overall
A	Labour cost						
	Human labour						
	Family	5012	4019	4515.5	9600	8690	9145
	Hired	3200	3800	3500	6059	6155	6107
	Machinery cost						
	Owned	Nil	668	334	2667	1997	2332
	Hired	1900	1000	1450	10300	9133	9716.5
	Bullock cost	4902	4887	4894.5	5114	4814	4964
	Total labour cost	15014	14374	14694	33740	30789	32264.5
B	Material cost						
	Seed	740	704	722	1421	1343	1382
	Plant protection	822	782	802	2063	1980	2021.5
	Organic manure	821	781	801	1289	1255	1272
	Irrigation	Nil	Nil	Nil	250	216	233
	Fertilizers	1026	978	1002	4170	3891	4030.5
	Total material cost	3409	3245	3327	9193	8685	8939
C	Total operating cost	18423	17619	18021	42933	39474	41203.5
	Interest on working capital @ 10%	1842.3	1761.9	1802.1	4293.3	3947.4	4120.3
D	Fixed cost						
	Rental value (1/6th of gross income)	3403	3050	3226.5	10677	9804	10240.5
	Revenue/Tax	25	25	25	25	25	25
	Depreciation	1500	1700	1600	1600	1800	1700
	Interest on fixed cost @10%	492.8	477.5	485.15	1230.2	1162.9	1196.55
E	Total fixed cost	5420.8	5252.5	5336.65	13532.2	12791.9	13162.1
F	Total cost (cost C_2)	25686.1	24633.4	25159.7	60758.5	56213.3	58485.9
	Managerial cost @10% of total cost	2568.61	2463.34	2515.97	6075.85	5621.33	5848.59
G	Cost C_3	28254.7	27096.7	27675.7	66834.3	61834.6	64334.4

Note : *in post NFSM shows *Kharif* paddy + Summer paddy.

in large farm. Among average material cost, 2.15 per cent of seed, 3.14 per cent of protection measures, 1.97 per cent of manures, 0.36 per cent of irrigation and highest among material cost *i.e.* 6:26 per cent of fertilizers were responsible in increasing total cost. Interest on working capital was to the extent of 6.40 per cent of total cost on various sizes of farms. Average rental value of land contributes about 15.92 per cent of the total cost which revealed increasing trend with farm size in absolute terms. Indicating the intensive cultivation of paddy crop by sample farmers.

The table 2 clearly shows that on an average total cost of (cost C_3) Rs. 27675.73 per hectare was required to produce paddy crop of which 59.97 per cent comprised for the variable cost commonly known as cost A_1. After adding interest on fixed capital to cost A_1, the cost went up to 61.73 per cent as cost B1 and when imputed value of land was further added it was increased up to 73.38 per cent. Thus, the remaining 26.62 per cent comprised of imputed value of family labour, and 10 per cent cost of the cost C_2 when added in this cost, it form total cost or cost C_3.

Table 2. Cost of cultivation of paddy crop cultivated during pre NFSM and post NFSM.

		(Rs/ha)							
S. No.	Particulars	Pre NFSM				Post NFSM			
		Small	Medium	Overall	By CACP	Small	Medium	Overall	By CACP
1	Cost A_1	16778	16418	16598	19462	36584	34559	35571	33169
2	Cost B_1	17271	16896	17083	20928	37814	35722	36768	36614
3	Cost B_2	20674	19946	20310	24604	48491	45526	47008	43010
4	Cost C_1	22283	21583	21933	24064	50081	46409	48245	42503
5	Cost C_2	25686	24633	25159	27740	60758	56213	58485	48899
6	Cost C_3	28254	27096	27675	27740	66834	61834	64334	48899

Table further inferred that cost A_1 to cost C_3 decreases with the increase in size of holding. The per cent of various costs to cost C_3 did not show any significant difference among different farms in cultivation of paddy on sample farm.

After the National Food Security Mission was implemented in the district all costs observed to have increased mostly because of irrigation cost which was earlier not so significant. One as the paddy was grown mostly in irrigated conditions. Here on an average total cost of (cost C_3) Rs. 64334.49 per hectare was required to produce paddy crop of which 55.29 per cent comprised variable cost commonly known as cost A_1. After adding interest on fixed capital to cost A_1, the cost went up to 57.15 per cent as cost B1 and when imputed value of land was further added it was increased up to 73.06 per cent. Thus, the remaining 26.94 per cent comprised of imputed value of family labour, and 10 per cent cost of the cost C_2 when added in this cost, it forms total cost or cost C_3. Table 2 further shows that cost A_1 to cost C_3 decreases with the increase in size of holding. The comparison of computed cost with the cost declared by CACP reveals that before the implementation of security mission, the cost was more than the actual cost but after the implementation of NFSM it seems to be lesser than the actual cost required.

The B:C ratio of paddy in small farms increased from 1.11:1 in pre NFSM to 1.15:1 in post NFSM and in medium farms it increased from 1.07:1 in pre NFSM to 1.12:1 in post NFSM (Table 3). The increased B:C ratio clearly indicated the positive impact of NFSM on paddy production.

The Triennium Average (TE) of minimum support price (MSP) of rice from 2003-04 to 2005-06 was Rs. 563.33 which increased at a rate of Rs. 10 only for the given three years. But the TE of MSP for the post NFSM period i.e. from 2006-07 to 2008-09 was 691.66 that increased at the rate of Rs. 135 per year. This is due to the implementation of NFSM which encouraged farmers to take up recommended package of practice that increased the cost of cultivation. As a result Government had to increase the MSP.

Table 3. Benefit - cost ratio of paddy crop cultivated under pre NFSM and post NFSM period.

		(Rs/ha)					
S. No.	Particulars	Pre NFSM			Post NFSM		
		Small	Medium	Overall	Small	Medium	Overall
1	Gross income	31515	29106	30310	76947	69849	73398
2	Total cost	28254.7	27096.7	27675.7	66834.3	61834.6	64334.4
3	Net income	3260.3	2009.3	2634.3	10112.7	8014.4	9063.6
4	B:C ratio	1.11:1	1.07:1	1.09:1	1.15:1	1.12:1	1.14:1

SUMMARY AND CONCLUSION

The investment in paddy production was more on small farms than that on medium farms in both pre NFSM and post NFSM periods in the study area. During pre NFSM period it was Rs. 28255 and Rs. 27097 per hectare for small and medium farmers respectively. But during post NFSM period it increased to Rs. 66834 and Rs. 61835 per hectare in case of small and medium farmers respectively. The price of paddy (MSP) set up by government was increased as cost of cultivation increased during post NFSM period. The small and medium farmers received incremental average net income during post NFSM period an average increment of Rs. 9065 per hectare during post NFSM period over the pre NFSM period. Benefit cost ratio (B:C) of small and medium farmers during pre NFSM period was 1.11:1 and 1.07:1 respectively. During post NFSM period, B:C ratio increased to 1.15:1 and 1.12:1 for small and medium farmers, respectively.

It shows that NFSM programme was significant impact on improving economic viability and profitability of paddy production in the study area. The higher yield of paddy through NFSM was due to quality seeds, proper irrigation, proportionate fertilizer use, adequate plant protection measures, etc. that were recommended through the programme. Promotion and adoption of these technologies through NFSM in more paddy growing areas of the region will boost up income generation and better standard of living of farmers. This can help to avoid crop failures and add a service to humanity by reducing number of suicidal events by farmers which is a major concern of the region.

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Economic impact of sole and biennial turmeric cultivation with mango and litchi as an intercrop

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ABSTRACT

An intercropping trial was conducted at twenty five farmers' field during 2011-2012 under agro-climatic conditions of North Eastern Plains Zone. The five combinations of different crops with turmeric were grown. The higher yield per plant (0.235 kg + 0.002 kg), yield per hectare (352 + 38 q/ha) and maximum rhizome diameter in turmeric (6.6 cm) was observed with biennial turmeric + wheat which were significantly better as other intercrops. The highest average gross return (₹ 241000), net return (₹ 99177), B: C ratio (1.70) and cost of production (₹ 6.25/kg) were observed in turmeric + litchi, followed by biennial turmeric + wheat and turmeric + mango cropping systems.

Key words: Sole and biennial turmeric, intercropping, litchi, yield, cost of cultivation

Turmeric (*Curcuma longa* L), the ancient and sacred spice of India which is known as 'Indian saffron,' is an important commercial spice crop grown in India. It is used in diversified forms as a condiment, flavouring and colouring agent and as a principal ingredient in Indian culinary as curry powder. It has anticancer and antiviral activities and hence finds use in the drug and cosmetic industries. Turmeric is propagated from rhizomes, which are ready for harvesting in about 7 to 9 months after planting (Kaur *et al.*, 2004). The turmeric is most suitable intercrop for different agri-horti systems of this region.

The litchi and mango based agro-horti systems are self-sustainable systems where solar energy can be harvested at different heights, soil resources can be efficiently used and cropping intensity is increased. The systems consist of two main components, *viz.* main crop and intercrop which occupy two different tiers in space of the production system (Singh *et al.* 2007). Fruit trees are efficient enough in providing higher economic return even under stressed conditions than other annual crops. The approach aims at improving productivity by effective utilization of air space which is not utilized in single tier system. The multitier system aims at sustainable management of natural resources like soil, water, space and environment. In case of annual crops, 74% of roots do not go beyond 50 cm soil depth, whereas in case of perennial crops, top 50 cm almost devoid of feeder roots (Awasthi and Saroj 2004). The spatially differential root distribution of different component crops in the system helps in higher nutrient and water use efficiency of the multitier system as a whole as a result of presence of feeder roots of the component crops at different depths (Saran and Kumar 2010). Again, the increase in organic carbon content in the soil due to decomposition of fallen leaves from the fruit trees contribute towards enhanced biological activity in the system leading to environmental stability in the rhizosphere. Among the intercrops, turmeric was found to be the most profitable under partial shade of mango and litchi orchards (Singh *et al.*, 2001). Traditionally, intercropping in interspaces of fruit orchards is practiced due to economic consideration (Awasthi and Saroj 2004) but only a few experimental results are available for turmeric based horticulture (Das *et al.* 2011). Turmeric has major role in socio economic life of North Eastern Plains Zone (NEPZ) farmers. The present study was undertaken to know the suitability and profitability aspects of intercrops in north Bihar

MATERIALS AND METHODS

The present investigations were carried out during 2011-2012 at Indian Agricultural Research Institute, Regional Station, Pusa, Samastipur (Bihar). The selected mango (Malda) and litchi (Shahi) orchard of twenty two years old trees, planted at 10 m × 10 m spacing received uniform cultural practices constituted as the experimental plant material. The intercrops grown were turmeric cv. Rajendra Sonia. The turmeric was sown 1.0 m away from the tree trunk leaving an area of 3 m^2 around each tree. The experiment was laid out in a randomized block design with five replications.

The observations on rhizome (turmeric), fruit (litchi & mango) and grain (wheat) yield were recorded during 2012-13. Twenty five farmers' fields were chosen for observations under different cropping systems. Five farmers' fields represented a replication. The observations were recorded to estimate the effect in different systems. The quantitative traits *viz.* yield per plant (g), yield (q/ha) and rhizome diameter (cm); soil fertility traits *viz.* pH, organic carbon (%), N (kg/ha), P_2O_5 (kg/ha), K_2O (kg/ha), cost of cultivation, returns, etc. were observed. The statistical analyses of the data were carried out using standard statistical procedures.

The cost of cultivation of turmeric based cropping system in one hectare was calculated as reported by Ganga (2007). Primary data were collected as per costs and returns during the period and analyzed as per the following procedures :

$$\text{Depreciation} = \frac{\text{Purchase price of asset - Junk value}}{\text{Number of expected useful years of life}}$$

After calculating total annual depreciation of the farm, the depreciation for a litchi and mango was worked out.

$$\text{Depreciation for crop 'X'} = \frac{\text{Total annual depreciation}}{\text{Total cropped area}} \times \text{Area under orchard}$$

Since the structure of cost for the cultivation of turmeric + wheat is quite different to the traditional crop farming, the establishment cost and maintenance (fixed and variable) cost concepts are devised.

Cost of production =

$$\frac{\text{Cost of cultivation per unit area} - \text{Value of by-product per unit area}}{\text{Quantity of main product produced per unit area}}$$

In case of different cropping systems except turmeric + wheat, the value of by–product was considered as zero.

Returns

i. Gross Returns : GR = QP x PP

Where,
GR = Gross return
QP = Quantity of produce
PP = Price of produce

ii. Net Return: It is the rest after deducting all cost items, *i.e.* total costs from the gross returns.

iii. Return over maintenance cost = Gross return - Total maintenance cost

For the present analysis, present value of future cash flow has been worked out by discounting the estimated returns and costs at 12% rate of interest, the rate of borrowing money from the financial institution in the study area.

RESULTS AND DISCUSSION

The pooled mean yield in terms of money indicated that the turmeric + litchi had yielded significantly higher returns due to better market price of litchi (Table 1). Analysis of the data revealed that yield improved significantly due to growing of biennial turmeric as intercrop. The five combinations of different crops with turmeric were grown. The higher yield per plant (0.235 kg + 0.002 kg), yield per hectare (352 + 38 q/ha) and maximum rhizome diameter in turmeric (6.6 cm) were observed with biennial

Table 1. Yield of turmeric and intercrops under NEPZ

Cropping system	Yield (kg/plant)	Yield (q/ha)	Prevailing rate (₹/q)	Rhizome diameter (cm)	By product (₹/ha)
Sole turmeric	0.141	176.40	500	4.78	--
Biennial turmeric	0.235	352	500	6.56	--
Turmeric + mango	0.142+166	142+166	500+1000	4.80	--
Turmeric + litchi	0.142+85	142+85	500+2000	4.78	--
Biennial turmeric + wheat	0.235+0.002	352+38	500+1285	6.59	+ 8000

turmeric + wheat which were significantly better as other intercrops. Turmeric + litchi intercrop was recorded highest yield (142 + 85q/ha) followed by turmeric + wheat intercrop (352 + 38q/ha). The positive influence of inter-cropping on growth and yield of turmeric has also been reported by Das *et al.* (2011) in aonla.

On an average, the total fixed costs per hectare were ₹30417, ₹48025, ₹30417, ₹30417 and ₹47617 for sole turmeric, biennial turmeric, turmeric + mango, turmeric + litchi and biennial turmeric + wheat cropping systems, respectively (Table 2). On an average, the total variable costs per hectare were estimated to be ₹76477, ₹114000, ₹105852, ₹104706 and ₹124784 for sole turmeric, biennial turmeric, turmeric + mango, turmeric + litchi and biennial turmeric + wheat cropping systems, respectively. Under total variable cost, harvesting, cultural practices, tractor charges, FYM, seed, *etc.*, involved higher investment in these cropping systems. Similarly, the positive influences have been also reported by Saran *et al.* (2010) in low chilling peaches. The average establishment costs were ₹10900 and ₹6700 for turmeric + mango and turmeric + litchi cropping

Table 2. Economic cost and returns (₹/ha) of turmeric and different intercrops

Sr. No	Particulars	Sole turmeric (₹)	Biennial turmeric (₹)	Turmeric + mango (₹)	Turmeric + litchi (₹)	Biennial turmeric + wheat (₹)
1	Fixed cost					
I	Interest on fixed capital	163	324	163	163	163
II	Depreciation	266	476	266	266	266
III	Land revenue	38	75	38	38	38
IV	Rental value	29950	47150	29950	29950	47150
A	Total fixed cost	30417	48025	30417	30417	47617
2	Variable cost					
I	Tractor charges	4863	4863	4863	4863	4863
II	Cultural practices	22313	44626	22313	22313	44600
III	Earthing up	8888	8888	8888	8888	8888
IV	Irrigation	2338	7011	4676	4676	7652
V	FYM	9600	9600	10600	10600	10000
VI	Fertilizers	3106	6212	3106	3106	5206
VII	Seeds	9625	10000	8010	8010	11400
VIII	Chemicals	69	-	3946	2800	-
IX	Harvesting	15675	22800	21450	21450	32175
X	Caretaker	-	-	18000	18000	-
B	Total variable cost	76477	114000	105852	104706	124784
C	Establishment cost	-	-	10900	6700	-
D	Total cost	106894	162025	147169	141823	172401
E	Gross return	88200	176000	237000	241000	232830
F	Net return	-18694	13975	49831	99177	60429
G	B : C ratio	0.83	1.09	1.34	1.70	1.35
H	Cost of production (₹/kg)	6.06	4.60	4.78	6.25	4.22

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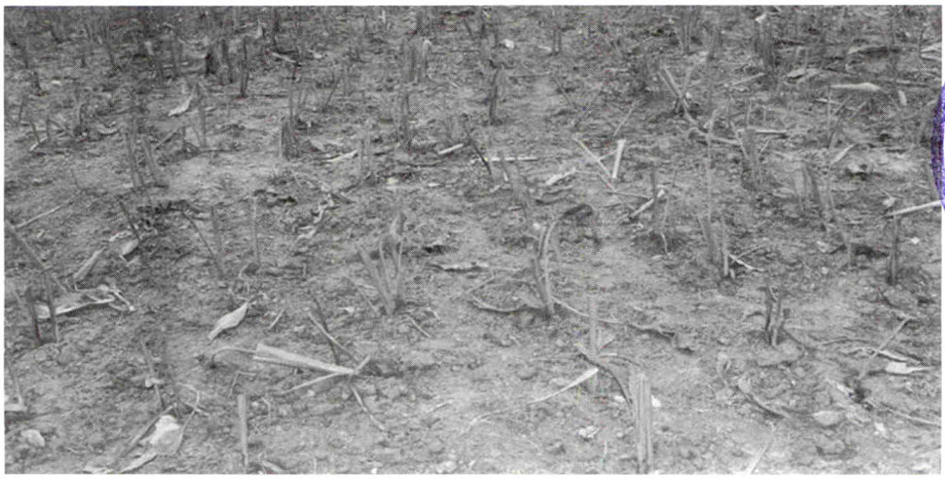

Fig. 1. Biennial crop of turmeric + wheat

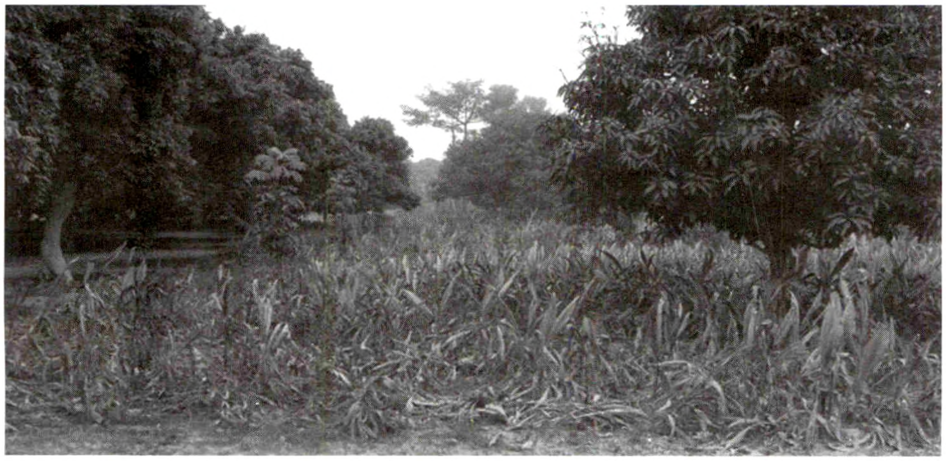

Fig. 2. Turmeric sown in litchi and mango orchard

systems, respectively. The higher establishment cost in turmeric + mango system was due to higher cost of mango per plant (₹ 60) as compare to litchi (₹ 25). The total cost was calculated to be ₹ 106894, ₹ 162025, ₹ 147169, ₹ 141823 and ₹ 172401 for sole turmeric, biennial turmeric, turmeric + mango, turmeric + litchi and biennial turmeric + wheat cropping systems, respectively.

The highest average gross return (₹ 241000), net return (₹ 99177), B:C ratio (1.70) and cost of production (₹ 6.25/kg) were observed in turmeric + litchi, followed by biennial turmeric + wheat and turmeric + mango cropping systems. Similar positive effect on costs and returns were also reported by Awasthi and Saroj (2004).

Improvement in soil fertility status (0-15 cm depth) in terms of pH, organic carbon and available N, P_2O_5 and K_2O was observed at par after two years of cultivation (Table 3).

Analysyes of the data revealed that the improvement of soil status over initial value is due to turmeric cultivation under different cropping systems in aonla (Das *et al.*, 2011). Overall the better results were observed with turmeric + litchi, followed by biennial turmeric + wheat and turmeric + mango cases as compared to other cropping systems. Turmeric has major role in socio economic life of farmers through high B:C ratio.

Table 3. Effect of intercropping on fertility status of soil

Intercropping system	pH	Organic carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Sole turmeric	8.31	0.52	214.90	22.85	130
Biennial turmeric	8.29	0.53	215.00	24.42	133
Turmeric + mango	8.29	0.54	217.30	24.14	136
Turmeric + litchi	8.27	0.54	216.10	24.40	137
Biennial turmeric + wheat	8.28	0.54	215.50	23.70	134
Initial value	8.32	0.52	214.60	21.50	130
CD (P=0.05)	NS	NS	NS	NS	NS

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